

Summary of the Invention

The present invention specifies new unique design shapes, features, and methods of operation which qualitatively improve and extend the scope of the transonic hull TH and the transonic hydrofield TH inventions of Patent Applications 08/814,418 and 08/814,017. The scope of the present invention is summarized below:

1. An extension of the operational speed envelope of TH over a very broad speed range increase by means of new design characteristics and new hydrodynamic regimes beyond the previous subcritical and supercritical regimes in the displacement modes, namely: the hypercritical, the transplanar, and the x-regimes. With these improvements, a single TH hull can operate with good efficiency over a large speed spectrum which otherwise would require two or three ships with different conventional hulls; for example, a conventional displacement ship at lower range of speed and a vee-bottom or semi-planing hull for higher speeds.

2. Another important feature of the invention pertains to hull characteristics and shapes above and below calm-water waterplane which are critical to permit successful operation over the broad speed regime in adverse seas, preferably also in optional combination with special longitudinal distribution of heavy mass components inside the hull, such as engines, fuel, and weapons.

3. A third feature of the invention pertains to special shapes, trim, balance, center of gravity location, location of longitudinal center of flotation, and various kinds of flaps and streaks needed to make feasible and enhance and improve the performance and maneuverability of the transonic hull in calm water

1 and adverse seas.

2 4. Additionally, other important features of the invention
3 are its hull shapes which have inherent low detectability by radar
4 and other sensors, as well as a wake of low visibility and thermal
5 content, which yields stealth properties to the hull which are
6 nevertheless compatible with efficient hydrodynamics and good
7 behavior in adverse seas.

8 Thus, the new invention is an all weather stealth transonic
9 hull capable of operating in new high speed hydrofield regimes of
10 the transonic hull, which now includes the hypercritical,
11 transplanar, and X regimes. For simplicity, the hull of the
12 present invention is also referred to in certain important cases as
13 TH-II, and its broadened hydrofield is TH-II. Other embodiments of
14 the present invention are improvements applicable to TH and TH-II.

15 Because the invention is broad and powerful, it is not
16 necessary to incorporate in a single vessel each and all features
17 and methods of the inventions and improvements, nor is it necessary
18 to incorporate each of them in all claims.

1 **Brief Description of the Drawings**

2 Figures 1, 2, 3 and 4 are examples of the prior art related to
3 this invention; are views of the cover planform and profile view of
4 TH, and planview of TH of the present invention;

5 Figures 5, 7a, 7b, 9, 10, 11, 12a, 12b and 14f cover examples
6 shown in previously filed application serial No. 08/814,418; and

7 Figure 8 specifies the relation between drag and V/\sqrt{L} for TH
8 and IACC hulls;

9 Figures 13a and 13b disclose the TH-II and TH-II in
10 hypercritical regime;

11 Figures 14a and 14b disclose the TH-II and TH-II in
12 transplanar regime;

13 Figures 14c and 14d disclose the stern profile and flap;

14 Figure 14e discloses the combination of the stern flap and
15 profile thereof;

16 Figure 15 discloses the TH-II and TH-II in X-regime;

17 Figure 16 discloses the stern and side flap for control;

18 Figure 17 discloses the TH and TH in sea waves with lateral
19 flaps for control;

20 Figures 18a-g disclose the TH 3-D shape for operation in
21 adverse seas and stealth operation;

22 Figures 19-28c disclose further embodiments and structures
23 associated with the TH and TH of the present invention; and

24 Figures 29-49 disclose further additional embodiments and
25 structures associated with the TH and TH of the present invention.

Description of the Preferred Embodiment

The nature and scope of the present invention can be better understood by reviewing the principal characteristics of conventional hulls, which have certain serious inherent problems in calm water and in an adverse sea, and examining also the limits and potential of transonic hulls TH and their hydrofields in Patent Applications 08/814.418 and 08/814.417, all which sets the conceptual inquiry solved by the present invention.

1. Characteristics and Problems of Conventional Hulls.

It is necessary for this review to separate the conventional hull designs by hull types in accordance to their operational speed envelopes. The envelopes are expressed for each hull type in terms of weight-to-drag ratios as function of speed-to-length ratios, best considered together with their corresponding volumetric coefficients, which are indicative of longitudinal surface and volume distributions responsive to their speed envelopes.

1a. Displacement Hulls.

Displacement hulls sustain boat weight by buoyant lift. As designed in the past and present, they have an upper speed limit called "hull speed," near and above which hydrodynamic resistance (drag) grows at a high exponential rate, for example, as in Fig. 1. The "hull speed" occurs when the length between bow and stern waves generated by and traveling with the translating hull equals the geometric length of the hull. This situation is expressed numerically when the ratio of boat speed in knots divided by square root of boat length in feet equals 1.34.

Displacement hulls are very efficient well below hull speeds with weight-to-drag ratio of over 100. At extremely low speeds,

1 the efficiency ratio increases to much higher values, because drag
2 approaches zero but weight remains constant. However, near or
3 above hull speed, their weight-to-drag ratio decreases rapidly and
4 becomes physically and economically unacceptable. Therefore,
5 higher speeds of displacement hulls is attainable principally by
6 increasing hull length. Unfortunately, the speed advantage of
7 length is not large. For example, the nominal "hull speed" of a 50
8 foot hull is 9.5 knots, but for 300 foot hull speed, it is only 23
9 knots.

10 The "hull speed" limit is intrinsic of displacement hulls,
11 because of their wave generation properties as they translate in
12 the water, i.e., "wave making." When the length of waves generated
13 by the hull exceed the geometric length of the hull, as shown in
14 Fig. 2, the situation becomes critical. The increasing size of bow
15 wave with increasing speed induces a further drop of the trough
16 near midbody, leading to incremental sinkage of the hull and an
17 increase of hull's angle of attack. There is also the additional
18 sinkage with speed increase due to the curvature of the hull below
19 local water levels. The increase of angle of attack impedes
20 further speed increase unless very large power is available to
21 climb over the bow wave and enter the planing regime, the
22 limitations of which will be discussed later on.

23 The high drag due to wave-making adds to and can exceed
24 friction drag, and is a very serious problem in the economics of
25 maritime transportation. Accordingly, considerable research has
26 been done in various ways to overcome it, unfortunately with only
27 minor improvements. For example, a bulbous bow may slightly
28 decrease drag at certain speeds. Also, long slender hulls are less

1 sensitive than beamy hulls, but carry less cargo, and have other
2 problems, as will be reviewed later on.

3 The principal characteristics of displacement hulls which
4 cause and determine their maximum operational speed envelopes are
5 available in various sources (for example, "A Comparative
6 Evaluation of Novel Ship Types," by MIT's Professor Philip Mandel)
7 and is summarized on the left side of Figs. 3 and 4. The
8 operational speed envelope covers speed-to-length ratios of 0.8 to
9 about 1.0 or 1.1 for commercial ships, which is well below their
10 "hull speeds" of 1.34. Military ships have speed envelopes that
11 include "hull speed" (for example, a cruiser ship at 1.35) and even
12 above "hull speed" (for example, the slender destroyer operating at
13 speed-to-length ratio of about 1.7). Above the speed ratios
14 described, the required size and weight of conventional power
15 plants and hydrodynamic problems of propulsion at the lower weight-
16 to-drag ratios become unacceptable for the missions of the ships.

17 Accordingly, there remains an urgent need for improving the
18 high speed efficiency and range of displacement hulls, at least
19 within their current speed limits and preferably in a breakout
20 above those limits. A practical solution is needed, especially if
21 it is able to eliminate wave-making drag of the type which limits
22 conventional hulls, without recourse to conventional hydrodynamic
23 planing.

24 1b. Planing Hull.

25 There is a widely held view that a different type of hull,
26 called planing hull, in which weight is supported by a hydrodynamic
27 lift force from momentum change (as distinct from buoyant lift),
28 can overcome the speed limits of displacement hulls, and

1 furthermore that they are *efficient* at high speed. Actually, while
2 planing permits high boat speed, it does so only for boats with an
3 approximately flat underbody having relatively light weight and
4 equipped with large propulsive thrust. The limiting
5 characteristics of this hull is the presence of dynamic drag due to
6 momentum change, shown in Fig. 5 for the limiting case of inviscid
7 planing. In practice, these hulls operate at angles of attack of
8 3° to 6° . The inviscid weight-to-drag ratio for optimum flat plate
9 planing case is 19 and 9.5 respectively.

10 When viscous drag is added to dynamic drag, the fact is that
11 planing is a grossly inefficient hydrodynamic regime, since the
12 best ratio of boat weight to resistance is in the order of 6 to 9,
13 as shown on the right sides of Figs 3 and 4. This is less than
14 half that of a modern jet transport flying about 10 times faster,
15 and only 1/10th (or less) that of a displacement hull of
16 "reasonable" length near, but below, hull speed. The operational
17 speed envelope of planing hulls are best exemplified by the ski
18 boats and similar sports craft which below their planing speeds
19 (for example, below a speed-to-length ratio of about 4) require a
20 nose-high attitude with large wave-making drag in displacement
21 mode, a condition similar to that shown for the lowest but longer
22 hull in Fig. 2.

23 Although the decrease of weight-to-drag ratio with speed in
24 Fig. 3 appears to be continuous with increasing speed-to-length
25 ratio, the left and right sides in Fig. 3 are not continuous, but
26 discontinuous as to shape and type of hulls - displacement and
27 planing - which have discontinuous and widely different volumetric
28 coefficients, as is clearly shown in Fig. 4. Thus, on the left in

1 Figs. 3 and 4, displacement hulls, if one includes destroyers,
2 cover an operational speed-to-length envelope from about 0.8 to
3 1.8, in which the weight-to-drag ratio decreases smoothly from over
4 120 (higher for slow tankers) to about 25, which the corresponding
5 volumetric coefficient decreasing smoothly from about 80 (higher
6 for slow tankers) to about 55 for destroyers. In contrast, on the
7 right sides in Figs. 3 and 4, planing hulls have an operational
8 speed-to-length ratio of the order of 3 to well above 4 (Fig. 3),
9 but with weight-to-drag ratios of about 6-8, and with a volumetric
10 coefficient of above 100 (Fig. 4), which is evidently much higher
11 than displacement hulls only because the latter are much longer.
12 The higher volumetric coefficient reflects the fact that planing
13 designs are not intended for nor are capable of sustained operation
14 near or below "hull speed" in which their low weight-to-drag ratio
15 would be prohibitive compared to displacement hulls.

16 As reviewed above, the displacement hull has a wave-making
17 drag component which increases strongly with speed near and above
18 hull speed, in addition to an approximately constant wetted area
19 generating friction drag which increases roughly with square of
20 speed. These drag sources combine into a high total exponential
21 drag growth near and above "hull speed" which was shown in Fig. 1.
22 As a result, operational speed-to-length ratios are about one for
23 commercial ships and somewhat below two for military ships.

24 The percent distribution of frictional resistance and wave-
25 making resistance, often referred to as residuary resistance
26 because it may include other minor resistance components, is shown
27 in Fig. 6. It shows that above "hull speed" of 1.34 more than 60%
28 of resistance is residuary - mostly wave making drag.

1 In hydrodynamic contrast, pure planing hulls, having a dynamic
2 lift roughly equal to weight, and a high dynamic drag component
3 dependent on a significant angle of attack required for vertical
4 equilibrium, and hopefully a decreasing friction drag percentage
5 with speed, operate at speed-to-length of order of 3.5 or more,
6 with low weight-to-drag ratio of the order of 8 or less, with
7 operations at lower speed-to-length ratios being an inefficient
8 transient condition, which also have very poor weight-to-drag
9 ratio.

10 Various hybrid vessels attempting to mix displacement and
11 planing hull characteristics of monohulls have been proposed in the
12 past in an attempt to arrive at a single ship type capable of
13 operating efficiently over speed envelope, unfortunately without
14 much success, as is reviewed below.

15 1c. Semi-Planing Hulls.

16 Unlike displacement hulls which have upwardly curved sterns
17 and curvatures at the bow, causing suction which sinks their center
18 of gravity with forward speed (increasing their apparent weight),
19 and unlike planing hulls having mostly flat undersurfaces and a CG
20 which tends to rise with forward speed, the semi-planing hull
21 usually has a Vee bottom and, for practical reasons, is heavier
22 than a pure planing hull. Although the semi-planing hulls can
23 generate the appearance of a "flat" wake at high speeds, their lift
24 is generated by a combination of buoyancy and dynamic forces, which
25 is inherently inefficient. These hybrids are longer and have lower
26 volumetric coefficient compared to those of planing hulls, but are
27 nevertheless much higher than for displacement hulls, as shown, for
28 example, at the middle of Fig. 4.

1 The borders of the wakes of semi-planing hulls, as seen from
2 an aerial view, appear flat and join together at some distance
3 behind the stern, generating a trailing "hollow" on the water's
4 surface, which can be interpreted, from the viewpoint of a fish
5 trained in hydrodynamics, as an virtual displacement hull of larger
6 length than that of the dynamic waterplane of the operational
7 semi-planing hull. The conventional semi-planing hull is an
8 inefficient hybrid: at slow speeds, it has excessive drag compared
9 to a good displacement hull. It requires very large power to reach
10 semi-planing speed, at which regime it is not as fast and is less
11 efficient than a pure planing hull. On the other hand, a deep-vee
12 semi-planing hull provides smoother ride for a greater payload in
13 a rough sea, and is more seaworthy than a planing hull. However,
14 it has a rougher ride than a displacement hull, with less favorable
15 sea keeping characteristics, and is commercially not viable for
16 most large maritime applications.

17 1d. Semi-Displacement Hulls.

18 As length-to-beam ratio is increased in slender hulls, wave-
19 making drag decreases. According to Saunders, slender displacement
20 power boats were common in the 1910s. Later on, the German Schnell
21 Boote (fast boat), having a round-bottom hull, was successfully
22 developed as an S-boat for WWII, performing well at high speeds in
23 the rough North Sea. However, as the length-beam slenderness ratio
24 of semi-displacement boats is further increased, the lateral
25 stability and payload capacity is further decreased. In the
26 extreme, an 8-man rowing shell relies on oars for lateral
27 stability. With a length-to-beam ratio of about 30, its wave-
28 making resistance is only 5% of the total at 10 knots, but its

1 weight-to-drag ratio is only 20, approximately. An appropriate
2 comparison in aircraft is the modern sailplane with a wing span-to-
3 chord ratio of 25. It can operate at weight-to-drag ratio of 40,
4 at 6 times the speed.

5 In the limit as the beam of slender hull approaches zero,
6 wave-drag tends towards zero, but viscous drag subsists and payload
7 capacity vanishes. Accordingly, recent development of high speed
8 semi-displacement boats have proposed a mixed lift mode, using
9 complex lateral or other additions to the slender hull, to generate
10 a hydrodynamic lift component at higher speeds, in order to
11 decrease buoyant lift component and its wave-making drag, and to
12 compensate other shortcomings of the slender hull at high speeds,
13 for example, lateral instability and/or a tendency for nose high
14 attitude and its high drag due to lift. As is the case for semi-
15 planing hulls, their speed potential is less than planing hulls,
16 and their ratio of weight-to-drag is not very satisfactory, and in
17 consequence, payload is not large. Although they appear to have
18 performance advantages over semi-planing near or above "hull
19 speeds" and are less sensitive in pitch, their complex shapes
20 appear to have an inherent size limit, as well as a lower speed
21 potential.

22 1e. Additional Resistance of Monohulls Due In Adverse Sea
23 Conditions.

24 The various types of monohulls reviewed above have different
25 responses to sea conditions, which sets crucial additional limits
26 to their efficiencies in most practical operations. This is an
27 important subject, since it can and does set crucial limits of
28 operational speed envelopes and impose structural weight and power

1 penalties which are different and significantly lower than would be
2 the case for designs of the same hulls operating only for calm
3 water.

4 In this writer's view, the drag and structural penalties in an
5 adverse sea for displacement and semi-displacement hulls originate
6 in their inherently unfavorable longitudinal distribution of volume
7 and of their buoyancy reserves, which are traditional and perhaps
8 applicable at slower speed envelopes for ships designed to climb
9 waves and which have inadequate speed margins relative to the
10 propagation speed of ocean waves. Moreover, the inertia values of
11 conventional ships would penalize their performance in respect to
12 the higher speed envelopes, if such higher speeds were otherwise
13 attainable with conventional displacement and semi-displacement
14 hulls. Obviously, a breakthrough to decrease the added drag and
15 weight penalties of displacement-related hulls in a sea is highly
16 desirable, particularly if it does not incur into the even worse
17 penalties which planing-related hulls encounter in an adverse sea,
18 such as their well-known "slamming" in an opposing sea. Slamming
19 occurs when quasi-instantaneous, large increases of angle of attack
20 relative to an oncoming wave are encountered, reaching off-design,
21 very large transient angles, which blunt speed and enormously
22 increases the structural loads and weight of the hull.

23 1f. Multi-Hulls.

24 The wave-making and other adverse drag problems of the various
25 types of monohulls reviewed above - including added resistance in
26 a sea - are so serious that considerable recent efforts have been
27 applied for the development of new multihulls. Although this field
28 is outside the scope of this document on monohulls, a few remarks

1 are in order. A pair of very narrow slender displacement hulls of
2 a catamaran, widely spaced laterally for stability, have been
3 successfully developed and are being used at high speed for various
4 commercial applications, especially in Asia. The calculation of
5 their volumetric coefficients can be deceptive, since there are two
6 hulls, each with half the weight but of full length. Hence, each
7 hull has a more favorable volumetric coefficient than a monohull,
8 but has two such hulls. Published information on lift-to-drag
9 ratios of modern catamarans are not readily available.
10 Nevertheless, drag estimates based on installed power and operating
11 weight indicate that weight/drag ratios of the order of 10 are
12 feasible for large semi-planing light catamarans at speeds of 50
13 knots and ratios of 16 for 25 knots, but with very small payloads
14 relative to their overall length and overall weight. These
15 weight/drag ratios are not high and are close to those of planing
16 hulls, but are achieved at higher speeds than for conventional
17 monohull displacement hulls.

18 Trimarans may have similar characteristics with some
19 structural gains, and they also have large traditional buoyancy
20 reserves forward, but only on the center hull. Recent multihull
21 trends are exploring trimarans with a very long displacement center
22 hull to retain a low speed-to-length ratio of the center hull, with
23 small, narrow, lateral hulls at high speed-to-length ratio for roll
24 stability, and to support a wide deck. Wave-piercing multihulls
25 may have a center body which has water contact only in swells,
26 providing the usual large buoyancy reserves in adverse seas, but
27 permitting wave piercing in middle seas. SWATHS are also
28 multihulls which rely on totally submerged primary displacement for

1 smooth riding, with penalties in wetted area and speed.

2 These multihull developments and other high speed hull
3 developments (see, for example, Jane's High Speed Marine Craft)
4 have so far been restricted to special commercial or military
5 applications, highlighting the need for ship manufacturers for a
6 new monohull design. Such has been specified in my Transonic
7 Hydrofield TH and Transonic Hull TH invention of Patent
8 Applications 08/814.418 and 08/814.417, capable of efficient
9 operation in subcritical and supercritical speeds as defined
10 therein, with drawings in which the water level is shown in calm
11 conditions.

12 2. Transonic Hull Characteristics, Applications 814,418 and
13 814,417.

14 As stated earlier, to understand the nature and scope of
15 present invention, it is also necessary to review, in addition to
16 the problems of conventional hulls, the limits and potential of the
17 transonic hull TH and its hydrofield TH of Patent Application
18 08/814.418 and 08/814.417, which precede the present Application in
19 filing date, including a review of results of tow tank tests.

20 2a. Characteristics and Features of TH and TH.

21 The TH is characterized in having a submerged portion with a
22 triangular waterplane shape with apex forward in static and in
23 dynamic conditions, a triangular profile, or modified triangular
24 profile in side view with maximum draft forward and minimum draft
25 aft, and planar lateral surfaces at large inclination or vertical
26 to the water. Thus, the submerged portion has a double-wedge
27 volume distribution with a fine narrow entry angle in planview and
28 a fine exit angle aft in profile view. Thus, the shape of TH, and

1 its associated hydrofield TH, is characterized in absence of
2 surface wave-making sources such as shoulder, midbody, or quarter
3 curvatures in planview; they have a narrow entry forward which
4 minimizes the water volume displaced per unit of time, and induces
5 special inboard underbody flow, favoring flow subduction which
6 eliminates the conventional wave-making pattern of displacement
7 hulls, and allows for new types of hydrodynamic ray phenomenon of
8 very reduced size and an absence of midbody trough. TH has a
9 favorable anti-planing propulsive pressure component at its
10 undersurface; favorable contracting streamline on the sides;
11 favorable gravitational pressure gradients on the hull's lower
12 surface; broad stern underflow which prevents pitch up and
13 eliminate stern wave, and favors the recovery of underbody energy
14 as well as that from following seas.

15 Accordingly, a very important feature of TH and TH as
16 specified in my prior Patent Application 08/814,418 is the
17 elimination of the below-water wave-making sources for high speed
18 operation in calm water within its displacement mode, thus
19 preventing or reducing the high exponential rise of wave-making
20 drag which characterizes conventional hulls near and above their
21 "hull speed." As explained previously, nominal "hull speed" is 1.34
22 when expressed with speeds in knots divided by square root of boat
23 length in feet. In this speed range, for example as in Fig. 1, the
24 wave drag component of total drag of conventional hulls grows
25 significantly, and hence the total drag grows in a high exponential
26 manner, typically by powers of the order of three or more,
27 depending on hull shape, beam loadings, and Froude number range
28 (Froude number is defined as speed in Ft./Sec. divided by the

1 square root of gravity acceleration times engaged water line length
2 in feet).

3 Hence, if the principal sources of wave-making drag growth
4 with speed are removed, as is the case of TH and of TH's archetype
5 shape of my Patent Application 08/814.418, then TH's principal
6 remaining source of drag growth with speed is that due to friction,
7 it being noted that (a) TH has no pressure drag problems at the
8 stern since it has a clean water exit, and (b) TH has greatly
9 reduced form drag, because it has no curved surface to
10 significantly increase local and therefore average dynamic pressure
11 along its wetted surfaces.

12 Summarizing, it is the objective and feature of TH's archetype
13 that near and above its "hull speed" while in the displacement
14 mode, its total drag grows with only the second power of speed.
15 The displacement operational mode is characterized in Patent
16 Applications 08/814.418 and 08/814.417 in its figures related to
17 the supercritical and subcritical speeds. For example, in TH:

18 • The wetted surface remains approximately constant for a
19 given weight;

20 • The water flow on the hull's sides continue as small
21 rays, and the lateral wetted surface remains approximately
22 constant, as is shown in Figs. 13 and 14 of original Application
23 08/814,418; and

24 • The undersurface of the hull has an approximately
25 constant negative angle of attack to the water surface, and
26 actually contributes a forward propulsive pressure force component,
27 which is opposing the retarding pressure components of the water
28 acting on the submerged sides of TH, as is shown in Fig. 13 of

1 original Application 08/814,418 and in Fig. 7 of the present
2 Application.

3 2b. Tank Test Data of TH and TH.

4 Curves from tow tank test of a TH archetype model (no
5 appendages) are shown in Fig. 8 of the present Application, showing
6 that, in the supercritical regime, which begins at about the speed
7 corresponding to the critical hull speed of a conventional
8 displacement hull, TH's total drag grows substantially with second
9 power of speed above "hull speed," within the speed limits of the
10 test, during which hull's pitch angle had no significant change,
11 and bottom and side wetted surface was observed to have no
12 substantial change. The drag growth to the second power can only
13 occur in the absence of growth of wave-making drag within that
14 speed range. The critical speed of a conventional hull occurs when
15 the length between the bow wave and its corresponding stern wave is
16 equal to hull's waterline length, and this occurs at a ratio of
17 speed in knots to square root of length in feet of 1.35.

18 By way of comparison, the drag behavior of a refined
19 International America's Cup Class hull (canoe only; no appendages)
20 tested in same tank at equal length, beam and weight as TH is also
21 shown in Fig. 8, showing substantially equal drag as TH at the
22 critical "hull speed" of a conventional hull, but a drag growth
23 above its "hull speed" greater than the second power and much
24 greater than TH, the IACC hull having experienced also a
25 significant increase of angle of attack with speed.

26 The test data of Fig. 8 indicates that the IACC hull has 40%
27 more drag than the TH archetype at a speed-to-length ratio of about
28 1.55, and 28% more drag at a speed-to-length ratio of about 1.75.

1 Due to speed limits of carriage, tests of TH model could not
2 investigate hydrofields at speed/length ratio greater than about
3 1.8.

4 The initial design speed to be selected for the square speed
5 growth of TH's total drag depends on TH's shape and on its ratio of
6 boat weight to cube of hull length, and can be lower than the 1.35
7 shown in Fig. 7, for example, by changing the angle in planview of
8 the sides of TH or changing the weight. For example, a 20% weight
9 reduction lowered the starting speed/length ratio of TH's
10 supercritical speed regime to 1.1, above which drag growth follows
11 only the second power of speed.

12 2c. Characteristics of TH as to shapes and propulsion.

13 Patent Application 08/814,417 as originally filed included
14 several drawings of critical alternative shapes of the lower
15 surface of TH below water and the shape of TH above water surfaces,
16 which were not shown in 08/814,418, and which are important in
17 relation to the stealth characteristics of the present invention,
18 and of the hull shape of the present invention in relation to TH's
19 ability to negotiate and successfully operate in adverse seas. The
20 review of these previous features and their extension and
21 improvements under the present invention will be made in a later
22 part of the present specification.

23 3. Conceptual Inquiry on Conventional Hulls Leading To Present
24 Invention.

25 The above review on the speed envelopes and limiting
26 characteristics of the various types of conventional hulls covered
27 in Sections 1-6 of the present Application, and of the transonic
28 hull covered in Section 7, leads to the following conceptual

1 inquiries, to which the present invention responds.

2 3a. Considering Figs. 3 and 4, which shows that three
3 different types of optimized conventional hulls, having well-known
4 hydrodynamic regimes such as displacement, semi-displacement, and
5 planing, are required to operate in calm water in a speed-to-length
6 envelope of less than 1 to greater than 5, is it possible to design
7 a single hull capable of operating in that broad speed envelope?

8 3b. If the answer to 3a is positive, would one expect that
9 the weight-to-drag ratios of the three types of hull types
10 optimized separately, efficiently, and covering by segments the
11 total breadth of speed-to-length ratios of Fig. 3, could be equaled
12 with a single hull type covering the same total broad speed range,
13 or at least approached over principal segments of the total speed
14 range; or could the weight-to-drag ratio of the new hull decrease,
15 or be improved, at least in part of the broad speed range?

16 3c. If the single new hull type is established, for example,
17 as in the present TH-II and TH-II invention, capable of operating
18 over the broad speed range currently requiring two or three
19 different hull types, each optimized in over 100 years of
20 development, could that new hull type have penalties in speed and
21 weight in an adverse sea which are larger than the penalties
22 suffered by the three types of hulls optimized also for adverse
23 seas in their respective speed envelopes, or could the penalties
24 for the new hull be less severe, or perhaps mostly eliminated?

25 3d. Assuming that a revolutionary new hull type achieves the
26 favorable characteristics described in 3a and/or 3b or to 3c above,
27 how should it be trimmed and controlled, and by what methods driven
28 and steered in a calm sea and in an adverse sea?

1 The above conceptual inquiry is ambitious, and it has been
2 focused and investigated, with the transonic hull TH of Patent
3 Application 08/814,418 as a starting reference point, as reviewed
4 below.

5 A reformulation of the conceptual inquiries of 3a to 3c is
6 focused below in more concrete terms:

7 3e. Is there an upper speed range in which practical
8 operation of TH Patent Application 08/814,418 in the displacement
9 mode encounters diminishing efficiency returns?

10 3f. If 3e is the case, qualitative changes or improvements or
11 methods or discoveries needed and feasible for TH and TH of
12 Application 08/814,418.

13 In respect to 3e, the writer first considers the supercritical
14 regime with absence of wave-making drag growth with speed. There
15 has to remain drag growth with speed of viscous origin, imperfectly
16 referred to as friction drag, which for a given hull size grows
17 necessarily with the second power of speed. Hence, there could be
18 encountered practical limits due to due to powerplant size
19 requirements, weight and costs which occur because power is a cube
20 function of speed growth, even if drag growth of TH is a second
21 power of speed, since power equals drag times velocity.

22 Moreover, there could be a performance limits as speed
23 increases, because TH archetype's propulsive pressure force
24 component in its lower surface shown in Fig. 7a is substantially
25 constant, because the hull's weight is substantially constant.
26 Hence, there is a diminishing percentage contribution of the
27 propulsive pressure force $-N\sin\beta$ shown in Fig. 7a, compared to
28 overall propulsive needs, which must oppose a friction drag growth

1 responding to the second power of speed.

2 3g. Diminishing Benefits of TH's Propulsive Pressure Force 3 With Speed Increase

4 The quasi-constant magnitude of propulsive pressure force
5 component of TH is a problem of significance for TH's overall power
6 requirement, which is illustrated below with a specific example:

7 • Assume a reasonable weight-to-drag ratio of 100 for a 700
8 foot long TH ship in displacement mode at a speed-to-length ratio
9 of 1.2 with a weight of 30,000 tons. According to Fig. 72, the TH
10 hull of Application 08/814.418 experiences in this regime a
11 propulsive pressure force component in its lower surface $-N\sin\beta$.
12 The high weight-to-drag ratio indicates that low total power is
13 required.

14 • The total drag for the example above is evidently
15 $30,000/100 = 300$ tons at a reference speed of $1.2 \sqrt{700} = 31.75$
16 knots. The dynamic pressure based on remote speed is $2,879 \text{ lb/ft}^2$.
17 The gross propulsive pressure force, GPF, on undersurface is -
18 $N\sin\beta$, according to Fig. 7a, where β is a negative of the
19 undersurface to remote water. If β is -4° , the $GPF = 2,097$ tons,
20 canceled in great part by opposing rearward components of pressure
21 forces on sides of TH shown in Fig. 7b. Therefore, the net
22 propulsive force NPF on the undersurface is by definition much
23 smaller than GPF, and much smaller than the 300 ton total drag.
24 Assume the NPF opposes 20% of total drag, i.e., 60 tons.

25 • We assume in this example that total drag growth with
26 speed for the TH archetype corresponds to that of an optimum TH
27 hydrofield; namely, drag growth is only that due to friction above
28 "hull speed," and that it increases only with square of speed.

1 This assumption has been verified by test data ad shown in Fig. 8
2 up to a speed-to-length ratio of 2, and is extrapolated beyond that
3 ratio in this example, in order to determine the effects of
4 increase of speed in the relative impotence of propulsive pressure
5 force on the weight-to-friction drag ratio of TH.

6 • If we double the initial speed to 63.5 knots, the drag
7 would be four times, i.e., 1,200 tons, the weight-drag ratio
8 decreases to 50 without accounting for changes in propulsive
9 pressure force, and the speed-to-length ratio increases to 63.5
10 $\sqrt{700} = 63.5 / 26.45 = 2.40$. The corresponding dynamic pressure is
11 11,516 lb/ft². However, the NPF, which remains a constant function
12 of weight at constant angle of attach of the hull, is now
13 diminished from 20% to 10% of total drag.

14 • If we triple the speed to 92.25 knots, the drag would go
15 up by a factor of $(92.25 / 31.75)^2 = 9$, reaching 2,700 tons, and the
16 weight-drag ratio is lowered substantially to 11.1, with a speed-
17 to-length ratio $92.25 / 26.45 = 3.48$. The corresponding remote
18 dynamic pressure is 25,911 lb/ft², and the contribution of NPF
19 becomes negligible percentage of the total propulsive force needed.

20 • If we quadruple speed to 127 knots, the drag would be
21 $(127 / 31.75)^2$ higher, i.e., 16 times higher, yielding 4,800 tons,
22 and the weight-to-drag ratio would decrease to $30,000 / 4,800 = 6.25$
23 at a speed-to-length ratio of $127 / \sqrt{700} = 4.80$. The remote dynamic
24 pressure is now 46,064 lb/ft², and the percentile NPF contribution
25 is virtually zero.

26 The above analysis permits the determination of the following
27 limiting characteristics of the TH archetype of Patent Application
28 08/814,418, answering part of the conceptual inquiry of 3a and 3e

of the present application:

3h. The friction drag term D for the weight-to-total-drag ratio at higher speed-to-length ratio reaches very high values under enormous remote dynamic pressure q . The viscous drag D_f is governed by the equation $D_f = KC_f qA$, in which A is wetted area, C_f is a viscous coefficient dependent on Reynolds number, and K is a factor to account for form drag and pressure drag. At speeds-to-length ratios of the order of two to four times higher than "hull speed," the weight-to-drag ratio of the assumed TH archetype decreases and could be as low as that of a planing hull, about 8 or less for the example analyzed.

3i. The propulsive pressure force on the lower surface of TH, which is important in the displacement mode near "hull speed" and necessarily a function of the apparent weight of TH and the sine of the negative angle β of TH's lower surface, becomes less and less significant as percentage of total propulsive thrust needed to overcome drag as speed increases, since the viscous drag, which total thrust must overcome, continues to grow with the square of speed at constant wetted area, whereas changes of weight with speed, even considering apparent weight increases under subduction flows at high dynamic pressure, and therefore of net propulsive underbody pressure forces, are obviously not as significant.

3j. The subduction flows — for example, flows f in Fig. 14c of Patent Application 08/814.418 — consequent of the negative angle of attack of the hull's undersurface, has the potential of increasing the apparent weight of the hull and increasing propulsive pressure force components, but would increase the wetted area of sides of the hull, which is unfavorable.

1 3k. Benefits of TH With Diminishing Percentile Propulsive
2 Pressure Force.

3 Notwithstanding the diminishing percent of propulsive pressure
4 force with increasing speed, reviewed under __ above, if it were
5 possible to reach high speeds for TH under a displacement mode with
6 reasonable powerplant cost and weight, it would have the very
7 important benefit that even if the weight-to-drag of TH were to be
8 as unfavorable at high speeds as that of a planing hull, TH, unlike
9 planing hulls, has a very favorable weight-to-drag ratio at lower
10 speeds, including the "hull speed" range; and

11 • Also, a broad speed envelope with comparable efficiencies
12 could be attainable with a single TH hull instead of two or three
13 types of conventional hulls, provided trim and control were
14 adequate for the TH case, and behavior in an adverse sea
15 acceptable.

16 3l. Summary of Results of Conceptual Inquiries Above.

17 The answer to the conceptual inquiry of section 3e is, yes,
18 there are improvements needed in TH and TH of Application
19 08/814.418 to overcome problems of increasing viscous drag with
20 speed (causing diminishing results of propulsive pressure force
21 components. And in respect to inquiry 3d, the answer is also yes,
22 in respect to trim, control, and effect of adverse seas. The
23 solutions to these problems, though difficult in the extreme, has
24 been attained theoretically and experimentally and is covered by
25 the teachings and embodiments of the present invention described in
26 the following section.

27 4. Objectives of Present Invention

28 The objectives of the TH-II and TH-II invention follow from

1 the need of a solution of the conceptual inquiries, namely:

2 4a. Establish new hydrodynamic conditions and speed regimes
3 for TH in which weight-to-drag ratio for increasing speed-to-length
4 ratio beyond 2 have improved efficiency.

5 4b. Achieve objective 5a in a manner that does not
6 deteriorate the favorable results already achieved for TH under
7 Application 08/814,418 at speed-to-length ratio below 2.

8 4c. Consequent to 5a and 5b extend the speed regimes of
9 operation of a single transonic hull TH-II, as may be needed with
10 special shapes, features, powered propulsive means, and various
11 design devices, to cover, with acceptable efficiency, a broad speed
12 range normally requiring more than one type of conventional hulls;
13 for example, the speed-to-length range of a conventional efficient
14 displacement hull under 1.35 plus that of a conventional planing
15 hull above 3.

16 4d. Achieve favorable objectives 5a, 5b and 5c in a manner
17 and with design characteristics that do not deteriorate in presence
18 of adverse seas any more than, and preferably less than,
19 conventional hulls.

20 4e. Achieves most or all objectives above in a TH-II
21 configuration that is stealthy in respect to radar and other
22 sensing methods.

23 4f. Achieve the above objectives, or a combination of these
24 objectives, with hull shapes, trim features, control devices, and
25 power arrangements that permit favorable operation and maneuvers of
26 TH-II under various sea conditions, including adverse seas and
27 winds, to achieve an all weather operational capability.

28 5. Substance and Details of the Present Invention.

1 In order to specify the new speed regimes which extends TH
2 hydrofield to TH-II, and the innovative improvements, refinements,
3 and certain crucial characteristics of TH-II, which have been
4 developed by R&D work of this writer, there is first reviewed the
5 hydrodynamics and speed regimes of TH of Application 08/814,418
6 shown in Figs. 10 and 11 of the present Application, within the
7 scope of the former application:

8 5a. Review of Supercritical Regime within TH Application
9 08/814.418.

10 This is the preferred hydrodynamic design condition of the
11 submerged transonic hydrofield for speed-to-length ratio near and
12 above hull speed under Application 08/814,418. Its surface
13 appearance is shown in Figure 10: the surface flow on the wake
14 region is approximately flat and tends on equipotential in the
15 gravitational sense in the region aft of the stern, but it includes
16 molecular agitation, because of friction below the undersurface of
17 TH emerging aft of the stern. Nevertheless, region 1 continues to
18 expand in a unique way, because of its highly directional steady
19 momentum, indicative of successful anti-wave subduction for optimum
20 performance of TH. The flow due to the principal volume displaced
21 by the translating TH emerges principally in region 1, with the
22 minimal surface alteration appearing as left and right three-
23 dimensional rays 3 and 5, having the minimal elevation shown by
24 hump 7 at downstream wake cut 9. This has been observed in tow
25 tank tests up to speed-to-length ratio of 2, which was a tank speed
26 limit.

27 5b. Review of Subcritical Regime Within Scope of Application
28 08/814,418.

1 This speed regime is shown in Figure 11, in which surface flow
2 fields of TH are approximately flat in region 11. But undersurface
3 viscosity forces, relative to momentum content of flow at
4 subcritical speeds, limits the shape and area of the wake at 11 to
5 a gothic arch type with aft border 11. Rays 13 and 15 have larger
6 humps. Downstream of flat wake 11, there is some eddy and hump
7 formations 17 and a central hump 21. In this sub-critical regime,
8 there may be in some cases drag growth with speed higher than
9 second power of speed, because of the eddies and elevations, even
10 though for TH there are no transverse stern wave nor a bow wave of
11 the type of conventional displacement hulls.

12 In both the supercritical and subcritical speeds, the
13 undersurface of TH in Application 08/814,418 is at a substantial
14 negative angle to the remote flow and experience a significant
15 propulsive force.

16 5c. Development of Hypercritical Regime for TH-II and TH-II.

17 To achieve operational capabilities of TH beyond the
18 supercritical range tested, new tests were necessary beyond
19 speed/length ratio of 2 to verify the theoretical view that the
20 underbody angle of TH should be governed to change from its initial
21 large negative angle to the surface, towards a much smaller
22 negative angle in order to generate a new hydrodynamic
23 characteristics in which, at constant weight, it was nevertheless
24 estimated that the lateral wetted surface of TH should be greatly
25 decreased in the presence of a decreased flow subduction. This
26 would lead to a more efficient, different 3-D flow behavior with
27 increasing speeds and dynamic pressures, since there was retained,
28 with a decreased lateral wetted area, the following:

1 • A hydrofield and hull without shoulders, midbody or
2 quarter curvatures;

3 • Lack of lateral outward flow and spray.

4 These characteristics were achieved with new and improved
5 hydrodynamic characteristics in the tow tank, trading off a
6 diminishing percentage of propulsive underbody pressure force, for
7 a significantly reduced drag from reduced lateral wetted surface,
8 resulting in a higher weight-to-drag ratios than otherwise for
9 speed-to-length ratios beyond 2 and of the order of 3. This
10 special different regime is called hypercritical to mark the fact
11 in that (a) no dynamic lift is possible since the undersurface of
12 TH remains at a greatly reduced but still negative angle, but (b)
13 nevertheless there occurs a decrease of lateral wetted surface.
14 The regime is uniquely efficient and to a critical measure a unique
15 property of the special triangular planform of TH, and its profile,
16 under effect of higher levels to achieve the higher dynamic
17 pressure in hypercritical regime, as will be described later on in
18 greater detail with aid of Fig. 13.

19 5.d Development of the Transplanar Regime for TH-II and TH-
20 II.

21 In the new model tests, as speed was further increased beyond
22 the hypercritical with the underbody governed to attain a very
23 small and critical positive angle which nevertheless provides
24 significant dynamic lift due to the very the high dynamic pressure
25 acting on a very large wetted planform, i.e., a low planform
26 loading, there resulted a fourth hydrodynamic condition and speed
27 regime, which nevertheless has a substantial decrease of wetted
28 length of the lower surface of the TH-II hull, compared to the

1 hypercritical case. I call this regime "transplanar" in that it
2 retains some lateral in-flow characteristic of the supercritical
3 regime of the transonic hull; that is, the flow direction does not
4 generate the predominantly outward flows typical of planing, which
5 are shown in Fig. 14f.

6 Summarizing, in this writer's R&D on transonic hulls, the
7 operational regimes, which in Patent Application 08/814,418 were
8 established to cover subcritical and supercritical cases, are now
9 extended and specified to much higher speed ranges, named
10 hypercritical and transplanar, which have weight-to-drag ratios
11 substantially more favorable and require less power than would be
12 the case if the TH of 08/814,418 were powered to achieve, in the
13 displacement mode, the same speed/length ratio range.

14 5e. The Supercritical Regime as a Preamble to Hypercritical
15 Case.

16 Fig. 12a shows, by way of referral, the hydrostatic ($V/\sqrt{L}=0$),
17 waterplane 24 representative of a TH having a length/beam ratio of
18 4.25 (beam not shown), and stern draft 23 with a draft-to-beam
19 ratio of approximately 0.015 for a weight/length ratio
20 (tons/[length in feet/100]³ of the order to 60. The undersurface
21 has a negative angle β establishing a draft at the bow much larger
22 than at the stern.

23 In dynamic condition above "hull speed," the side elevation in
24 respect to remote waterplane of TH in supercritical regime changes
25 to that shown in Fig. 12b. Notice that although dynamic stern
26 draft 25 is zero, the undersurface angle β and draft at bow as well
27 as deck angle remains substantially unchanged, but propulsive
28 pressure 27 is significant. The corresponding surface of the

hydrofield is shown already in Fig. 10.

5f. Specification of (for) TH-II Body and TH-II Flow in
Hypercritical Regime

To increase speed beyond speed/length ratio of 2, this writer theorized that the higher momentum content of the wake of TH-II permitted and justified a rearward shift of the center of gravity, shown in Fig. 13a as an increase in the hydrostatic ($V/\sqrt{L}=0$) draft 29 with a draft-to-beam ratio of about 0.02, still retaining a deep draft at the bow. However, in the dynamic condition, while the hydrodynamic draft relative to the stern's wake becomes substantially zero in Fig. 13b, as in Fig. 12b, the undersurface angle is reduced to β^1 in Fig. 13b, substantially smaller than β in Fig. 12b. β^1 , while negative, can approach zero. This change of angle of attack is not predictable with a bow and shoulder wave of a conventional hull (see Fig. 2), because there is no shoulder wave on TH-II, and its bow wave is minimal. The small angle β reduces the total propulsive force, but it was confirmed in new model tests that it reduces also the viscous or friction drag on the sides of TH. While the surface appearance of the corresponding flow appeared as in Fig. 10, it has different three-dimensional flow field components which cannot be related to planing, as no surface component of the hull has positive angle of attack with respect to the remote flow, but nevertheless reduces the wetted area in the sides of TH. The attainment of this condition, in which hydrostatic weight must be substantially equal to displaced water, is altered in respect to Fig. 12b by the reduction of apparent weight due to greatly decreased subduction, and a decrease of propulsive pressure force without significant deterioration in

1 surface or wake of the hydrofield. The new regime is named
2 "hypercritical," and was attained with propulsive thrust
3 approximately parallel and below the undersurface located as in
4 prop shaft 33 to provide nose up pitch up couple with respect to
5 TH-II's drag with arm 37 of approximately 0.5 units (0.007% LOA).
6 Alternately, if thrust line is inclined upward as in prop shaft 35,
7 it can provide a lifting force equal to thrust times sine of angle
8 39. For example, if weight-to-drag ratio were 75, drag would be
9 $W/75$ and a 10° angle at 39 would result in a lift force of $0.0024W$.

10 The specifications for Fig. 13b differs from and is improved
11 in respect to Fig. 12b as follows: large change of angle of
12 undersurface from β to β^1 ; a large reduction of bow draft from
13 approximately length 26 to a much smaller value 38; a substantial
14 reduction of lateral wetted area and of propulsive pressure on the
15 undersurface, an increase of dynamic pressures and momentum content
16 on the wake, and an aft shift of center of gravity, combined with
17 certain effects of thrust line in this case from propeller but
18 could be water jets as well. The complex combined action of the
19 changes above produce the hypercritical regime and results in
20 greatly improved weight-to-drag ratio for speed/length ratio of
21 order of 3, or more, that is, in the range usually assigned to
22 larger vee-bottom semi-planing boats. Notice, however, that the
23 performance in the hypercritical regime has not impaired the
24 surface appearance of the wake of Fig 10, but TH-II now operates in
25 three regimes: subcritical, supercritical, and hypercritical, and
26 prevents a wake with a significantly depressed surface.

27 The above description of Fig. 13b is feasible for and unique
28 to the TH configuration because its flat sides are devoid of

1 shoulder, mid-body, and quarter curvatures which are usual wave-
2 making sources, and because the maximum beam of TH is adjacent the
3 stern, and therefore collects the entire underbody momentum flows
4 and discharges it in flat exit wake with high momentum content
5 which continues to prevent transverse stern wave formation.

6 A word of caution in respect to Fig. 13b is the limit of
7 center of gravity shift to the rear, since it has to meet both
8 supercritical and hypercritical regimes. Wrong choice can produce
9 a tendency for self-sustained pitch oscillations similar to an
10 aircraft "phugoid" mode, which can become unstable and divergent.
11 The CG location for Fig. 13b requires certain limits, reviewed
12 later on.

13 5g. Specification of TH Body and Flow in Transplanar Regime
14 for TH-II and TH-II.

15 When speed of TH is further increased beyond the hypercritical
16 regime of Fig. 13b, an entirely new hydrodynamics was theorized,
17 named herein "transplanar" in that it permits a uniquely efficient
18 partial dynamic lift condition without the type of outward lateral
19 flow which penalizes conventional semi-planing or July 3, 2000
20 planing, while retaining the transonic hull features which also
21 yield and permit supercritical, and hypercritical regimes. The
22 hydrodynamics and hull conditions are described with the aid of
23 Fig. 14. Before describing Fig. 14, however, a review is made of
24 conventional planing boat design of advanced design, for example,
25 that of Fig. 14f, so that the qualitative differences of the
26 transplanar regime can be appreciated. Conventional planing is
27 characterized as follows:

- 28 • A planing hull below the planing speed sinks at the

1 stern, increasing angle of attack due to large bow and shoulder
2 waves as shown on bottom of Fig. 2.

3 • If the boat's underbody has suitable surfaces and there
4 is sufficient power, the planing boat climbs over its bow and
5 shoulder wave and enters the planing regime of Fig. 14f.

6 • Outward flow 41 in Fig. 14f with lateral spray is a
7 consequence of lift requirement by momentum change of conventional
8 planing shapes.

9 • Minimal planing area A_p shown as 43 in Fig. 14f in
10 contact with water provides lift with minimum wetted area,
11 resulting in high area loading, a quotient made by dividing boat
12 weight W by planing area A_p .

13 • Relatively high planing angle of attack caused by small
14 area A_p ; results in high momentum drag component due to lift, as
15 was explained already with the aid of Fig. 5.

16 • Small planing area A_p , 43, compared to overall area of
17 hull's planform 43 + 45, results in high slamming loads in an
18 adverse sea on area 45, causing high pitch oscillations, amplified
19 by large hull volume above area 45.

20 • High beam loading at stern, a quotient obtained by
21 dividing weight W by beam 47, results in a deep wake and high angle
22 of attack.

23 • A disturbed wake comprising, in cross-section view,
24 hollows 49 and protrusions 51, are symptoms of high momentum drag
25 in addition to lateral flow losses.

26 • A wake planform that, unless disturbed by propeller
27 slipstream, has a hollow which usually closes downstream of the
28 stern with a large hump 53, a symptom of drag.

1 • As explained earlier, the large area portion 45 and
2 associated volume above it, which is dry only in calm water but
3 becomes engaged repeatedly in waves, causes high slamming loads
4 plus large change of buoyant forces, leading to excessive cyclic
5 structural loads, severe pitch and heave accelerations which can be
6 intolerable for occupants and cargo, and require slowing the
7 operational speed of conventional planing hulls in adverse sea.

8 Overcoming all of the above problems of conventional planing
9 hulls, TH-II of Fig. 14 is shown in its transplanar regime in
10 profile in Fig. 14b and in planview in Fig. 14a. The contrasts and
11 large benefits of TH-II's transplanar regime are evident in the
12 following description:

13 • There is no shoulder wave on TH over which TH must climb
14 to enter a transplanar regime.

15 • Large planing area A_p , 61, compared to small dry planform
16 area 63, permits the generation of adequate momentum lift with a
17 small positive angle α , which cannot become large because of the
18 location of max beam at stern of TH-II.

19 • Low transplanar area loading, W/A_p , because A_p 61 is
20 large.

21 • Inherent low angle of attack α of the hull, feasible for
22 adequate lift with low area loading, W/A_p .

23 • Low momentum drag with adequate momentum lift, due to
24 inherent small value of α .

25 • Lack of lateral energy dissipating flows from TH-II in
26 the transplanar regime, in favor of typical TH's side rays, not
27 withstanding adequate momentum lift, a unique advantage of the TH-
28 II planform in transplanar flow.

1 • Low beam loading at stern, achieved by placing a large
2 maximum beam at stern, allowing also low area loading.

3 • Superior low energy wake achieved with low α , low W/A_p
4 ; low W/B^1 , lack of outward flow, with low energy rays instead, and
5 absence of outward lateral spray flows, as is pointed out in
6 pertinent transplanar claims.

7 • Excellent behavior in adverse sea because the ratio of
8 dry planform area 63, to wetted planing area 61, and to total area
9 $63 + 61$, is small in smooth seas, whence the dry volume
10 corresponding to area 61 is also small, whereby slamming loads and
11 added buoyant lift in adverse seas produce minimal effects in
12 pitch, thereby avoiding high structural loads and accelerations, as
13 is pointed out in pertinent transplanar claims.

14 Specifically, Fig 14a shows in planform a transonic hull
15 having its archetype triangular shape, similar to that of Fig. 10
16 and 11. However, the hydrodynamic regime in Fig. 14a is entirely
17 different from Fig. 12, and also different from conventional
18 planing hull. In Fig. 14b in the transplanar regime, the hull is at
19 a very small positive angle β^{11} , shown with numeral 65, with a
20 wetted length 61 and a dry length 67. It is evident that, contrary
21 to a conventional high speed planing hull, the dry area 69 is
22 considerably smaller than 61, which greatly reduces slamming loads
23 in an adverse sea. Also, volume above length 69 is much smaller
24 than above length 67, reducing added buoyant forces in an adverse
25 sea. In a calm sea, surface of wake shows a unique absence of
26 lateral spray, indeed retaining lateral rays of the type of Fig.
27 10, which is contrary to, and not possible in, conventional planing
28 hull. These unique features of TH-II's are the subject of

pertinent transplanar claims.

Certain critical geometric relations leading to the unique hydrodynamics and superior sea keeping of TH-II, which apply to the hypercritical and transplanar regimes, and the x-regime (see later on), are illustrated in the following example, specified not by way of limitation. In the example, the numerals pertain to Fig. 14, and the numbers identified as units could be feet, tens of feet, meters or other units:

- ▶ LWL = LOA = numerals 67 + 69 = 70 units
- ▶ B, beam numeral 62 = 16 units
- ▶ LWL/B = 4.375
- ▶ Entry planform angle 60 = 13 degrees
- ▶ Planing length, numeral 67 = 35 units
- ▶ Dry length in Fig. 14, numeral 69 = 35 units
- ▶ Hull's total planform area = 560 units squared
- ▶ Waterplane area wetted, subcritical, supercritical, hypercritical = 560 units squared
- ▶ Dry planform forward transplanar, calm water = 140 units squared
- ▶ Wetted planform transplanar, calm water, 560-140 = 420 units squared
- ▶ % waterplane area loaded hypercritical = 100%
- ▶ % waterplane area with additional load in adverse seas = 0%
- ▶ % waterplane area loaded calm water, transplanar, 420/560 = 75%, transplanar
- ▶ % area with transient additional load transplanar in adverse seas = 140/560 = 25%
- ▶ Weight of boat = W

- 1 ▶ Planform loading = $W/420$, calm water, transplanar
- 2 ▶ Planform loading = $W/560$, hypercritical
- 3 ▶ Beam loading all conditions $W/16$
- 4 ▶ Average free board height, numeral 64 = 5 units
- 5 ▶ Volume above waterplane, transplanar = 2100 units cubed
- 6 ▶ Volume above forward dry planform, transplanar = 700 units
- 7 cubed, partially engaged only in rough water
- 8 ▶ Ratio of volume forward to volume above waterplane $700/2100 =$
- 9 0.33

10 The above design criteria and characteristics of TH, though
11 not limiting, are unique. Moreover, they require, for safe
12 transplanar operation, a proper location of center of gravity (CG),
13 longitudinal center of flotation (LCF), and thrust line, such that
14 the behavior in calm and adverse seas are adequate. The center of
15 gravity needed to meet the required conditions in transplanar flow
16 depend on hull shape in planform in profile, and thrust line
17 location. A good value for CG location for the above example is 28
18 units measured forward from the stern, i.e., 40% of LWL, with the
19 thrust line approximately parallel to the undersurface and 1.25
20 units below it, i.e., 2.85% LWL below it. The above unique
21 features are characteristics for claims.

22 Furthermore, to achieve a transition from hypercritical to
23 transplanar regimes on TH-II with a stable CG, the corresponding
24 aft profile shape is shown as 71 in Fig. 14c, for approximately the
25 last 2.0 units of length of the undersurface, shown as 73, having
26 a length of 2.5-3.5% of LWL which should be inclined upwards at
27 approximately -5 degrees, as shown by angle $-\alpha$. This is
28 qualitatively different and contrary practice to profile shape of

1 high speed planing boats, which recommend opposite downward camber
2 at stern to facilitate planing without excessive angle of attack,
3 and also reduce hump drag before planing; for example, to alleviate
4 nose-up tendency at bottom of Fig. 2.

5 The critical importance of hull shape, CG, and control flaps
6 to be specified in next sections can be better understood by
7 recognizing the variables involved in pitch equilibrium as
8 hydrodynamic regimes change from zero speed to transplanar in calm
9 water and in a sea. Consideration has to be given to hydrostatic
10 center of buoyancy, hydrodynamic center of buoyancy during hull
11 motion, longitudinal center of flotation (LCF, area centroid of
12 waterplane) which changes radically in transplanar regime, center
13 of dynamic pressure forces due to momentum change, effect of change
14 of hull's angle of attack on hydrodynamic subduction, the
15 respective interaction of all the above in calm water and in an
16 adverse sea.

17 For example, in the example reviewed above in which the CG is
18 28 units from stern, i.e., 40% LWL, the center of longitudinal
19 flotation (waterplane area centroid) varies from 23.3 units from
20 stern (33% of LWL) in supercritical regime, to roughly 15 units
21 from stern (21% of LWL) in transplanar regime. Accordingly, the
22 critical distance between CG and LCF vary from $(28 - 23.3)$ units =
23 4.7 units for supercritical and hypercritical regimes, which is
24 6.7% LOA, to $(28 - 15)$ units = 13 units, which is 18.5% of LOA, in
25 the transplanar regime. An approximate position is shown as
26 numeral 70 in Fig. 14a.

27 These important parameters and relationships pertaining to
28 longitudinal trim, stability, and control have been exemplified for

1 the transonic hull of the proportions reviewed, with a trailing
2 flap of the type shown in Fig. 14d described later on, with the
3 hull having rounded corners between sides and bottom surfaces of
4 radius 1 unit, which is 6.25% of stern's beam.

5 Variations of the hull's geometry in the example above will
6 alter somewhat the parameters and relations of longitudinal trim,
7 stability, and control. They are also dependent on ratio of weight
8 to volume, for example, weight in tons to cube of length in
9 feet/100. The example given is a guide for ratios in the order of
10 50 to 85. By way of reference, a ship of 30,000 tons and 750 feet
11 LWL has a weight-to-volume ratio of 71.1. In this respect, it is
12 important to distribute the loading of transonic hull to cause a
13 much greater hydrostatic draft at bow than at stern.

14 To realize the unusual features of TH and TH-II if flotation
15 with a static waterplane were made such that TH's undersurface were
16 parallel to the waterplane, as is usual for conventional ships, the
17 center of buoyancy would fall at about 33% LOA, requiring the same
18 position of CG, it would cause excessive drag in displacement
19 supercritical regime, and would negate the large distances between
20 CG and LCF of transonic hull in its various regimes, and would
21 cause an unstable pitch situation at higher speeds. Also, TH's
22 stern's wake in supercritical regime would be destroyed. With such
23 parallel flotation, the remedy to move CG forward for pitch
24 stability would require a submerged nose bulb on a transonic hull,
25 which would impair drag and be undesirable in an adverse sea,
26 resulting in slamming loads and large variations of structural
27 bending moments at midbody.

28 5h. Stern Devices to Make a Single TH Operational in Various

1 Speed Regimes.

2 To make feasible a flexible and efficient use of the single
3 transonic hull TH over its entire broad speed range - i.e.,
4 subcritical, supercritical, hypercritical, and transplanar regimes
5 - variable geometry stern profile is of critical and optimum
6 results, for example, with a trailing edge flap at the stern, but
7 used in a qualitatively different critical and opposite way than
8 stern tabs on conventional planing or semi-planing boats.

9 Fig. 14d shows TH's undersurface with a flat aft profile 75
10 adjacent stern 77, with a stern flap 76 mounted smoothly at the
11 corner of surfaces 77 and 75, with an upward flap angle S_f of about
12 -6° , and a stern flap chord of 2.5% LWL. This negative angle is
13 needed to generate and govern the critical small angle 65 in Fig.
14 14b in transplanar regime with a stable 40% CG, and in certain
15 cases in subcritical regimes, but not desired in supercritical or
16 hypercritical regimes.

17 Fig. 14e shows the stern flap of Fig. 14d installed in the
18 type of stern of Fig. 14c modified to accept an optimized hull aft
19 profile. Specifically, there is flat profile aft of hull 78 which
20 curves gently to the rear in sector 79 of 4.2% LOA, thereby
21 reducing stern's draft about 0.18, thereby increasing immersed
22 volume contribution of rear of TH-II, without excessive local stern
23 draft. At corner 83 there is hinged a stern flap 82 of about 2.1%
24 chord operated from torque tube 86 by a connecting rod between arm
25 85 and bracket 84. The flap has an angle of about -5° for
26 transplanar flow, and optionally for subcritical flow up to about
27 -8° . However, the flap reverses the effect of downwards curvature
28 79 to about zero exit angle at stern flap position 88 for

1 supercritical and hypercritical regimes, and has a special brake
2 position 89 which buries the bow of TH and raises its stern for a
3 drag increment from both sources, especially beneficial for braking
4 in hypercritical and transplanar speed regimes.

5 I have reviewed with the aid of Figs. 12, 13, and 14, the
6 specifications for shape, hydrostatic and hydrodynamics of TH in
7 supercritical, hypercritical, and transplanar regimes, center of
8 gravity and LCF locations and thrust line locations, planform and
9 beam loadings, rear profile shape of TH, stern flap for TH and
10 their combinations, the distribution of dry and wetted undersurface
11 areas and corresponding volumes, and their effects on hull behavior
12 in adverse seas. For the latter case, an increase of weight
13 permits a more aft CG location; for example, for weight-to-length
14 ratio of 76, the CG can be moved back from 0.40 to 0.39, and also
15 at lighter weight-to-length ratio to permit easier entry to the
16 transplanar regime.

17 5i. Additional X-Speed Regime of TH

18 Fig. 15 shows a new regime which has been developed by this
19 writer's R&D on a transonic hull. It is of such a peculiar nature
20 that even its relation to the transonic hydrofield premises and
21 understandings are not entirely explored, although the absence of
22 shoulder, midbody, and quarter curvatures of TH remains critical
23 and most beneficial. But the water-surface conditions appear to
24 defy full understanding, and is therefore identified as the X-
25 regime, encountered in the higher range of speeds, testimony of
26 which are photographs showing the surface conditions specified in
27 Fig. 15 at, around, and to rear of the stern 91 of TH body 90. The
28 wake has a flat even depression with a smooth left edge 93 and a

smooth right edge 97 which project rearwards as water extensions of the flat sides of body 90. Wake cross-sections at 96 and 95 show a flat surface of wake below the level of undisturbed flat water-surface areas 92 outboard of depression at 97, and 94 outboard of depression 95. There is no evidence in the wake of rays projecting to rear of transom 91, except as borders of the depressed wake zone. For this x-regime, it is noted, TH has a deeper draft forward as outlined with dash-lines in Fig. 15. The pervasive flat surfaces of the flow field outside the confines of the wake, as well as inside the wake, is evidence of an extraordinary hydrodynamic regime, in which it is possible to postulate a fully lateral flow component in the wake of $V \sin 4$ with V being boat speed and with 4 being half the planform's bow angle.

5j. Roll Control for TH with Stern and Lateral Flaps and Bottom Streaks.

Fig. 16 shows trim and control devices for TH of special value for turns of TH in the hypercritical and transplanar modes. On TH 13, there is wide stern 100 having at its lower edge three stern flap segments hinged at collinear axis 107. The center flap segment 103 acts principally to provide nose-up trim during a turn, and is therefore raised up by angle 102 in respect to a projection of flat lower TH surface 112. The flaps are shown for right turn. Right flap 101 is raised by angle 104 larger than 102, to sink right side of hull 113, and left flap 105 is lowered by angle 106 in opposite direction than angle 104, to raise the left side of TH 113. Accordingly, TH banks to the right and the bottom surface of TH experiences, when yawed to the right under action of conventional rudder, a centripetal force component to the right,

1 which generates a curved path to the right, under Newton's second
2 law. (Rudder not shown in Fig. 16.)

3 An alternative turning method is shown in Fig. 16, comprising
4 a retractable lateral flap 108 hinged at an axis 109 inclined in
5 profile view to have a positive angle of attack α relative to the
6 flow on the sides of TH. The deployed position of flap 108 shown
7 in Fig. 16 causes an added lift on right side of TH 113, and since
8 the left flap 114 remains retracted, the right side of TH is
9 raised, causing a turn to the left. For rectilinear motion, right
10 flap 108 is retracted by its actuation piston 111 and is nested
11 smoothly in depression 109 on the side of TH.

12 Another detail of Fig. 16 is the cross-sectional curvature
13 used at the lateral lower corner of the hull. The right side
14 curvature corresponds to a local ellipse sector with major axis
15 vertical and 2:1 ratio used in certain speed regimes of Fig. 14a to
16 minimize sinking effects of subduction. A different embodiment is
17 shown at left side with a nearly sharp corner 116, which is best
18 used for x-regime of Fig. 15. As a consequence, the left lateral
19 flap 114 can be placed at a lower position on the sides of TH 113,
20 with more powerful effect.

21 The mode of usage of stern flaps of Fig. 16 is described in
22 tabular form below in which β represents angles relative to the
23 rearward projection of hull's undersurface 112 in degrees.

Flap position	Left flap	Center flap	Right flap
Subcritical, straight	-4	-4	-4
Hypercritical, straight	-5	-5	-5
Hypercritical, right turn	+2	-7	-10

Transplanar and supercritical use of stern flaps for right turns is similar to hypercritical.

The regimes of use of lateral flaps of Fig. 16 are in the supercritical, hypercritical, and transplanar regimes, with a longitudinal length that can be optimized, if desired, for the preferred speed regime, for example, as outlined below.

5k. Lateral Flaps for Hydrodynamic Functions.

Fig. 17 shows lateral devices which have various applications, as follows:

a. Dry deck function: the lateral flaps on TH 120 are deployed when operating in adverse waters, for example, in presence of wave 122, compared to calm water level 121. Under these conditions, a properly designed TH will penetrate the swells with minimal loss of speed, but there may be some water from the swells reaching the top of the freeboard during the penetration. This situation is minimized by right and left lateral flaps 123 forward, 124 at midbody, and 125 aft. The flaps may be similar to flaps 108 in Fig. 16.

b. Pitch control function. In high speed regimes in chopped water or in swells, or even in calm water, selective use of lateral

1 flaps can be used for pitch control; for example, deploying the
2 forward lateral flap pair 123 only for pitch up, or the aft lateral
3 flap pair 125 for nose down pitch of the hull.

4 c. Lateral control function. Only one flap of midbody flap
5 pair 124 can be used for roll of the hull without pitch effects, or
6 only one flap of pair 125 can be deployed for roll towards the
7 opposite side, which would not have its flaps deployed, and nose
8 down pitch.

9 d. Heave control. In the high speed range, the deployments
10 of the entire flap set will generate some heave, or the deployment
11 of midbody flap pair 124 will generate midbody heave adjacent CG
12 with minimal pitch effects.

13 e. Fixed lateral flaps as walking paths: As an alternative
14 (of lower cost), and at some loss of calm water performance,
15 permanent lateral flaps can be used for operation in normal and
16 adverse seas, and also to serve as paths to have crew walk on them
17 in the fore and aft direction for inspection of window seals for
18 forward anchor manipulations forward, etc.

19 51. Roll Control with Vertical Undersurface Fences.

20 Fig. 17 also shows a vertical fence-like surface 127, which
21 can be adapted to be retractable bottom flap for minimum drag in
22 rectilinear motion. When rudder 126 is rotated, it will generate
23 a centrifugal force at the stern, say outward of the paper. This
24 will yaw the stern towards the right. As outward motion is
25 developed, a lateral water flow component inwards towards fence 127
26 is developed which raises the pressure on the right side of fence
27 127 and therefore rolls TH right side upwards. The combined action
28 of yaw by the rudder and roll by fence 127 causes the generation

1 of a centripetal force on the hull towards the left, causing a left
2 turn path in accordance to Newton's second law. The centripetal
3 force has two parts: one is the inward component on the bottom of
4 the hull, and the other is the inward force on the right side of
5 the hull. Combined they can generate very tight radius of turn.

6 5m. Unique Size Effect on Efficiency of Full Size TH Vessels.

7 My analysis of my tests, I further discovered a very subtle
8 but very important advantage in estimating the weight-to-drag ratio
9 of a TH ship applicable to certain hydrodynamic regimes of TH, as
10 determined in model tests. The advantage is a unique function of
11 size increases for TH's hull, which is not present in the increase
12 of size for conventional hulls. Since the drag growth with speed
13 of TH in displacement supercritical, hypercritical, and hydrofield
14 regimes is principally of viscous origin and wave-making phenomena
15 or drag of momentum change is much less significant over these
16 speed ranges compared to conventional displacement or planing hulls
17 in the same speed range, TH's weight-to-drag ratio improves with
18 increasing size for various reasons; one important reason is that
19 viscous drag decreases strongly with Reynolds number as size
20 increase at constant Froude number. For example, if drag
21 coefficient with increasing scale from model to ship decreases 50%,
22 and if, for simplicity, the viscous drag were estimated with the
23 cube of the scale, it would be diminished by 50%, but the wave-
24 making drag and the weight would be calculated with the cube of the
25 scale. Moreover, since a wetted area increases with the square of
26 the scale, there would be a further reduction of viscous drag. The
27 practical consequences of TH's reduction of wave-making drag in
28 displacement mode in model tests is that the W/D ratio of a TH ship

1 predicted from model tests can be estimated to be 20% or more than
2 that predicted from model tests of a conventional displacement ship
3 at same speed, size, and weight.

4 5n. TH Shapes for Solving General Problems in Adverse Seas.

5 Ships and displacement boats have been designed in the past
6 and present with substantial buoyancy reserves, and these are
7 larger from about midbody up to the bow, which reserves are
8 transiently engaged in adverse seas, to raise the ship's bow when
9 encountering waves. Even displacement ships such as destroyers
10 having a sharp entry at the bow at waterplane level and narrow
11 waterplanes are nevertheless flared outwards and forward above
12 waterplane to provide buoyancy reserves, as well as permit open
13 decks forward protected from adverse seas by fences above deck
14 level.

15 Monohulls with vee bottoms and planing boats also have
16 substantial buoyancy reserves and planing type surface reserves
17 from midbody to the bow, for the same purposes.

18 It has also been the practice of conventional ships and boats
19 to place heavy components amid-ships, to reduce pitch inertia.

20 The TH design departs from, and is contrary to, these
21 traditional monohull approaches in respect to shapes and volumes
22 for adverse seas, with several important departing TH design
23 features, exemplified in Figs. 18a to 18g.

24 Fig. 18a shows planview 130 of TH with a length of 70 units
25 and max beam aft of 16 units. Fig. 18b shows side view contour 132
26 above static water 134; and submerged profile line 136. Figs. 18c
27 to 18g show cross-sections of TH. The following unique features
28 are noted:

- 1 -- A very sharp total entry angle in planform into waves at
- 2 all levels above and below waterplane as shown in Fig.
- 3 18a, and confirmed by cross-section 18c, 18d, 18e.
- 4 -- A reduced free-board and profile height above static
- 5 waterplane in the forward third of hull as shown in Fig.
- 6 18b.
- 7 -- A greatly reduced volume in forward region of the hull
- 8 above static waterplane, evident in the transverse cross-
- 9 section Figs. 18c to 18f.
- 10 -- A traverse cross-sectional shape distribution above
- 11 static waterplane in the forward region of the hull that
- 12 has falling shoulders or an inverted vee shape to
- 13 dissipate vertical loads from waves being pierced, as
- 14 shown in Figs. 18c to 18f.
- 15 -- An enclosed habitable volume in the forward portion of
- 16 the hull to permit piercing of waves as shown in Figs.
- 17 18c to 18f, instead of conventional designs taking in
- 18 water on top of an open forward deck.

19 The specific shapes of TH successfully tested in adverse seas
20 are shown in Figs. 18 reviewed above, characterized further in the
21 following:

- 22 -- In Fig. 18a, an entry angle extending to the sides of
- 23 hull below and above waterplane at total angle 138 of
- 24 approximately 13°, over the entire length of the hull
- 25 -- Low profile with vertical freeboard forward of
- 26 approximately 4.2% of the length of hull at 80% station
- 27 from stern, as in Figs 18b and 18d
- 28 -- Cross-section of hull above waterplane with inverted vee

1 as in Figs 18d and e, or inverted U as in Fig. 18f, with
2 a smooth low overall profile with a maximum height above
3 waterplane of approximately 7% of overall length.

4 A critical parameter is the resulting volume of buoyancy
5 reserve in the forward region of the hull above calm waterplane 134
6 which can be displaced as a transient condition, for example,
7 during a transient diving encounter into a large wave, such as wave
8 131 in Fig. 18b. This additional volume should be related to the
9 water volume displaced by the weight of the ship in calm water.
10 Successful tests of TH have been made with volume ratios in the
11 order of 13% for the additional volume between 80% station and bow
12 in Fig 18b, and on the order of 32% for the additional volume
13 between station 57% and station 80%, with a hull's center of
14 gravity at approximately 40% station. These ratios were obtained
15 by graphic estimates which are necessarily rough in nature, and can
16 be refined by computerized calculations with software having wave
17 simulation, although the latter criteria is incomplete because the
18 asymmetry of the forward aft area of waterplane. These ratios
19 result in minimum heave and pitch disturbances.

20 Referring back to the TH-II planform and profile in Fig. 18, it
21 is very important and critical to clarify that the dynamic loading
22 at high speeds of the hull, for example, under action of wave 131,
23 is considerably smaller than conventional very slender boats, such
24 as that shown in *Sea Horse* publication of November 1994, for the
25 following reasons:

26 • At high speed, TH has near-zero or a very small angle of
27 attack such as in Figs. 13 and 14, and therefore the change of
28 vertical momentum of TH is much smaller than with very slender

1 hulls having dynamic lift assist and which at speed tend to ride
2 nose high with a large portion of the hull's dry area and volume
3 exposed to wave's impact and therefore capable of generating very
4 large loads.

5 • Furthermore, the planview of TH is much sharper for a
6 given hull beam, because it is triangular with max beam at stern,
7 rather than with lenticular sides with max beam near midship, as is
8 shown in other U.S. patents. Thus, for a given profile, the volume
9 of buoyancy reserves of TH is less in forward region.

10 • Cross-section forward has an inverted vee shape to
11 prevent extremely high local loads under dynamic water impact when
12 piercing a wave or from waves breaking on top of the hull such as
13 would be in the case if, instead of having an inverted vee, there
14 would be an inverted cup.

15 With TH geometric properties, it becomes especially
16 advantageous to distribute the heavy components of the ship to
17 maximize the longitudinal moment of inertia, i.e., that about a
18 transverse axis through the center of gravity at 40% station in
19 Fig. 18b, and an alternative one through the longitudinal center of
20 flotation at 33% of station in Fig. 18a and b, although the latter
21 criteria is incomplete because of the asymmetry of the fore and aft
22 areas of waterplane. Placing powerplant, heavy weapons, fuel
23 tanks, and other heavy areas adjacent bow and stern are important.
24 The model tests have shown very favorable results with as much as
25 40% of the total boat weight assigned near the hull's ends. This
26 may necessitate, in certain cases, the unusual powerplant
27 distribution shown in Fig. 19.

28 50. Weight distribution of TH.

1 Fig. 19a shows in side view a TH 150 having a forwardly
2 located engine 152 driving a midbody propeller 154 driven through
3 a conventional shaft, both protected by vertical fin 156 which can
4 also provide good tracking and centripetal forces in a yaw. At the
5 rear are a pair of left and right engines, only one of which is
6 shown as engine 156. It drives a vertical shaft 158 which is
7 submerged in rudder 160 to drive propeller 168 mounted on the
8 rudder, or separate and ahead of the rudder. The power plant
9 system can comprise therefore three engines. Fuel tanks 151 and
10 153 are also located at extremes of the hull, so that heavy
11 components maximize pitch inertia of the hull. The upper part 161
12 of hull 150 is similar to that of Fig. 18 in the forward half, but
13 in the aft half there is an open deck having two additional
14 features which combine uniquely with the broad stern beam: one is
15 a helicopter landing pad 164 above deck. Another is a stern garage
16 170 in Fig. 19b for launching and retrieving an auxiliary powerboat
17 172, while the TH ship is in motion. Fig. 19b also shows how to
18 fit right engine 156 and tank 151 on right side of garage with left
19 engine 174 with left tank 176 on left of garage, and stairway 178
20 out of garage. All of which is uniquely possible by max beam at
21 stern.

22 5p. Stealth and Low Observable Characteristics of TH

23 Returning to Fig. 18, I now describe the stealth anti-radar
24 surface arrangement of Th above waterplane 134. Specifically, the
25 envelope of the hull follows a faceted criteria of low radar
26 signature, which I review on the right side of the hull, having
27 flat panels shown in the cross-sectional views 18c to 18g,
28 comprising flat panels 138 inclined at about 45° to the waterplane,

1 flat panel 139 inclined at about 90° to the waterplane and top flat
2 panel 140. Thus, directly from above the hull presents only three
3 panels: 138 left and 138 right, both inclined at 45°, and flat
4 panel 140, approximately horizontal. From an oblique side view
5 from above on right, there are only three significant panels: 138
6 right, 139, and 140. From the front view, by its nature, the TH
7 shape is extremely stealthy. From the rear, it's detectability is
8 limited to four dispersing oblique surfaces: 141 and 142 on the
9 right, and corresponding pair on the left, without numerals.

10 5q. Center of Gravity and Waterplane Centroid of TH

11 Other important details in Fig. 18 is the center of gravity
12 145 CG location at 40% of hull length from stern, and the
13 longitudinal center of flotation 143 LCF at 33% of length from
14 stern, really a waterplane centroid, providing thereby a dynamic
15 stabilizing arm between CG and LCF of $40\% - 33\% = 7\%$ of boat length
16 in displacement mode, as already mentioned for other figures and
17 which is a radically larger number than possible for conventional
18 displacement ships, and is uniquely feasible with, and advantageous
19 for, TH. In the transplanar mode, this margin is increased
20 substantially above 7%, and can reach the order of 14% in reference
21 to transplanar LCF 143TP.

22 5r. Undersurface Shape and Construction Methods for TH

23 As specified in original Patent Application 08/814,417, modern
24 construction methods using composite, or stamped metal sheet and/or
25 welded plates can be used for TH; also wood can be utilized.

26 However, TH can be designed for low cost fabrication methods,
27 taking advantage of its unique simplicity of shape, especially with
28 the use of prefabricated composite sheets, marine plywood or sheet

1 metal, which can be used in flat elements, and/or with gentle
2 single curvature panels, to obtain hydrodynamically smooth
3 surfaces.

4 Original Patent Application 08/814,417 also specified Figs.
5 20a, 20b, 21, 22, 23, 24, 25, 26 and 27, without change (except
6 sequential numerals and minor grammatical corrections).

7 Fig. 20a shows an isometric bottom view of TH comprising flat
8 rectangular lateral sides 200 and 203, converging at bow 204 in
9 triangular planform; a flat triangular bottom 205, with centerline
10 202; and a flat stern region 206. This shape, with a wetted
11 triangular profile, as reviewed earlier, transcends wave-making
12 drag of conventional hulls , but may have excessive wetted area and
13 viscous drag.

14 Fig. 20b shows TH refined with simple construction methods to
15 reduce viscous drag by introducing additional triangular flat at
16 the undersurfaces of the hull, modified to have a hull with flat
17 trapezoidal sides 221 and 223 converging at bow 224. The
18 undersurface comprises three triangular flats 229 at left, 225 at
19 middle with centerline 222, and 227 at right. The triangles
20 terminate in flat stern region 226.

21 Figure 21 shows a pure triangle surface development of TH in
22 which its sides and undersurfaces of the hull are defined by
23 triangular flat surface elements 231, 232, 233, 234, 235, and 236
24 converging at bow 237 and terminating at stern region 238.

25 Figure 22 shows a shape developed from Figure 21, but more re-
26 fined to further reduce viscous drag. Its undersurface and side
27 surfaces comprise main quasi-triangular surfaces 241, 243, 245 and
28 247, between some of which there are trapezoidal or triangular

1 fairing strips 242, 244 and 246, all of which blend in bow 248, now
2 extending at an angle 250 to the vertical to reduce the rate of
3 volume engagement per unit of time as function of draft. Surfaces
4 242, 243, 244, 245 and 246 extend rearwardly towards a flat transom
5 249 of little depth, shown vertical only for clarity of drawing.
6 The upper deck surface adjacent to the transom is now at an angle
7 240 to the forward deck surface, defining a rearward sub-triangular
8 termination to side surfaces 241. For ease of construction, in
9 Figure 22 elements 242-246, and even 244, could be rectangles of
10 very high aspect ratio, the principal gain being lower cost of
11 fabrication.

12 Figure 23 shows a variation of TH, in which, when there are
13 practical restrictions to hull length and/or hull beam (such as
14 design rules, or available dock length for docking, or maximum beam
15 for trailering purposes, all of which may impact on water length
16 and/or righting moments for a given displacement). It may be
17 necessary to modify the TH archetype of Figure 19. For example,
18 hull shape shown in Figure 20 meets greater displacement for a
19 given maximum beam with a modified quasi-triangular arrangement for
20 a given maximum beam.

21 Specifically, in Figure 23 the main component of the hull com-
22 prises a main triangular body of length 254 extending between bow
23 251 and the triangle's base station 252 in the manner shown in
24 previous figures. But, in Figure 23 the hull is now extended aft
25 with an aft body of length 255, extending between triangle's base
26 station 252 and stern region 253. Note that although the extension
27 is quasi rectangular in planform at deck level along 255, the
28 submerged undersurface remains flat with main triangular surface

1 components 256 and 257, and flat near triangular surface components
2 258 and 259, extending to transom 260.

3 A special feature for TH shown in Figure 23 is the use of
4 vertical or anhedral winglets 261 and 262 at the rear and of the
5 hull, to extract energy from the fan-like submerged flow field
6 along surfaces 258 and 259, thereby increasing the hull's effective
7 beam at transom 260, without increasing its geometric trailerable
8 beam for the case of vertical winglets. If these winglets are
9 inclined by an ahedral angle as on the left side of Figure 23, they
10 can begin to act as rear hydrofoils supporting part of the weight
11 otherwise supported by hull extension 255, and they can also serve
12 for directional control.

13 It is noted that in Figure 20 to 23 the submerged undersurface
14 have been flat or nearly flat, guided by surface elements and
15 hydrodynamic waterplanes having triangular features, with
16 decreasing draft and increasing beam as the water moves towards the
17 rear, setting a favorable gravitational hydrostatic pressure
18 gradient for the flow which remains active in hydrodynamic
19 condition.

20 The development of shapes using flat surface components
21 reduces fabrication costs and helps illustrate design features.
22 Penalties are small by reason of unique cooperation between the
23 simple shapes of the TH archetype permitting use of flat and/or
24 single curvature elements to attain a reasonably smooth double
25 wedge TH body.

26 5s. Some Special TH Shapes for Sailboats

27 Figure 24 shows a further variation of the TH archetype, this
28 time modified in order to meet arbitrary rules such as IACC:

1 minimum girths, and underbody slopes which require bow and stern
2 overhang from the waterline length at centerplane. For TH, the
3 stern overhang can be important, as is exemplified in Figure 24,
4 developed from 23. Specifically, the TH archetype extends on main
5 hull body length 274, from bow 271 to maximum beam at triangle's
6 base at station 272, having a center line 276 on its undersurface.
7 Aft hull extension 275 extends from station 272 to 273, for the
8 centerline on its undersurface has to be inclined by angle 276 for
9 rule overhang purposes, no more than approximately 12°, defining a
10 200mm distance 280 at an aft girth station 279. The stern is Vee-
11 shaped in planform, to permit a suitable girth 282 within IACC
12 rule.

13 Figure 26 shows my archetype hull in inverted position for
14 clarity, having lower surface triangles 290r and 290L, and a
15 modified stern with inverted Vee or diagonal transom sides 293 and
16 294, defining an internal a triangular stern exit with a forwardly
17 oriented apex at centerplane. This reduces wetted area without
18 decreasing heeled waterline. Netting 291 supported by tubular
19 member 292 effective "deck" area, but with a decreased hull weight.

20 The hull (canoe) of Figure 26 is designed to be able to
21 operate under sail, engaging left or right hydrodynamic waterplanes
22 on one or the other half of its undersurfaces, 290L or 290R, which
23 decreases wetted area. Planing may be desirable if it increases
24 hydrodynamically the hull's hydrostatic righting moment, or
25 otherwise decreases total drag.

26 Figure 27 is a unique development of this writer's TH hull
27 with a very deep-v transom cuts 296 and 297 defining a triangular
28 recess for flow exit at the stern. The deep-V geometrically

1 parallels, with stager, the triangular bow entry of the hull.
2 Under sail when upright, it has decreased wetted area. When upwind
3 or reaching, the hull of Figure 27 should be heeled to one side or
4 the other, establishing engaged hydrodynamic waterplane shapes 297a
5 when rear end 297 is engaged by the water, and 296a when side of
6 196 is engaged. A large weight savings and wetted area reduction
7 results from the deep Vee, with a large effective "deck" area
8 retained by bar 298 and netting 298a.

9 Figure 27 also shows special appendages for TH hull under
10 sail, comprising a rotating fin keel 299 which can be moved along
11 arc 299c, and right and left rudders 299b and 299a, either of which
12 is engaged when sailing upwind; for example, 299b when side 197 is
13 engaged according to waterplane 297a. In that case, the trailing
14 edge of both fin 299 and rudder 299b should be rotated to the right
15 in the figure, or clockwise. Rotating fin keel 299 could be
16 substituted by a non-rotating narrow fin and a large rotating flap.
17 Foil rotation permits operating the TH hull at a trans-leeway angle
18 shown in Figure 28, instead of the usual leeway angle, with
19 decreasing hydrodynamics drag due to rectilinear leeward canoe
20 shape and increasing sail thrust by increasing gap 300 between jib
21 301 and main sail 302 when sailing close hauled. Also shown in
22 Figure 28 are the corresponding rudder foil angle positions, with
23 299a out of the water.

24 Fig. 28A shows a multihull using two parallel TH hulls 301 and
25 303 which at supercritical speeds and above have no wake
26 interference in the vicinity of the vessel, as can be seen by
27 inboard ray patterns 309 and 311. Outboard rays are 313 and 315.
28 The hulls are driven by propellers 305 and 307. Hence, the

1 hydrodynamic TH benefits are retained in full.

2 Fig. 28B shows a radically different multihull approach
3 exemplified with TH hulls, but applicable to other hulls.
4 Specifically, right and left hulls 310 and 312 have their
5 longitudinal axis of symmetry outwardly oriented in a toe out angle
6 in respect to a general axis of symmetry. As a consequence,
7 outboard rays 320 and 322 have diminished size and drag effect,
8 with less wetted side surface, but inboard rays 324 and 326 tend to
9 interfere tending to raise water level and drag, and increase
10 inboard wetted surfaces. This may be recovered by favorable
11 interference at the rear end of hulls 310 and 312. However, the
12 multihull of Fig. 28B is equipped with water accelerating
13 propulsive means 330 shown as a battery of five water jets between
14 the hulls which when operational recover certain energy content of
15 rays 324 and 326, reducing their tendency to increase water level,
16 reducing their drag contribution, reducing inboard lateral wetted
17 surfaces, and increasing efficiency of thrust generation in that in
18 addition no boundary layer from hulls falls into the powerplant.
19 The clean accelerative flow appears as 332.

20 Fig. 28C is a trimaran with three TH hulls 340, 342, and 344,
21 but also could be conventional hulls with no toe out, since for
22 either case, the two propulsion batteries 346 and 348, each of the
23 type in Fig. 28B, which provide unique interactive benefits of
24 decreasing drag and increasing thrust. For smaller multihulls, the
25 power groups can be made with batteries of outboard marine engines.
26 The following additional remarks pertain to Figs. 28A: For a given
27 overall length and weight, the catamaran configuration offers
28 unique benefits to TH, in that the beam loading, for a given hull

length and entry angle, is halved, facilitating the more rapid transition from supercritical to transplanar hydrodynamic regimes on both hulls.

In respect to Fig. 28B, the benefits of toe out angle need not be restricted to hulls having longitudinal axis of symmetry, and an asymmetric planform can replace the angle of tow out, or diminish it, it being understood that the asymmetric shape of the hull would be symmetric in respect to a central longitudinal line.

In respect to Figs. 28B and 28C, the word "batteries" is used to indicate a single flow propulsor, or multiple flow propulsion, mounted between the hulls of multihulls of the referred figures, for example, the five water jets of group 332 in Fig. 28B, or the pair of two water jets 346 and 348 in Fig. 28C.

I refer now to Fig. 29 showing a long center TH hull 360 and the much shorter lateral TH hulls 361 and 362 forming a TH trimaran, with unique cooperation between the three hulls components, exemplified in the following quantified analysis:

Lc, length of center hull = 350 feet

$Lc / Bc = 7$

Bc, beam center hull = 50 feet

$\sqrt{Lc} = 18.70$

Speed / length ratio, $V / \sqrt{L} = 4.27$

Speed = 80 knots

Lo, length of outboard hulls = 125 feet

Bo, beam of outboard hulls = 25 feet

$Lo / Bo = 125 / 5 = 5$

Speed = 80 knots, same as center hull

1 $V / \sqrt{L_o} = 80 / \sqrt{125} = 80 / 11.18 = 7.15$

2 Ratio of lengths $L_c / L_o = 350 / 125 = 2.8$

3 Ratio of speed / length ratios, center / outboard = $4.27 / 7.15 =$
4 0.60

5 $L_c / B_oa = 350 / 175 = 2$, where B_oa is overall beam

6
7 Important hydrodynamic characteristics of Fig. 29 are as
8 follows: minimal interference drag, for example, between non
9 colliding principal rays 363 and 364 good alignment of hydrostatic
10 centers of buoyancy of the three hulls for good hydrostatic lateral
11 stability lower length / beam ratio of outer hulls, compared to
12 center hull, to decrease beam loading and therefore the induced
13 drag of outer hulls.

14 The importance of the latter feature is indirectly exemplified
15 in Fig. 30 showing drag curves, which is qualitative in nature.
16 Curve (a) shows the drag growth between speed / length ratios of
17 4.27 and 7.15, which is large at constant beam loading, but when
18 beam loading is decreased by increasing beam relative to length,
19 and / or by decreasing weight, as in curve (b), drag is reduced.

20 A different and less favorable situation is shown on the left
21 side of trimaran of Fig. 31, having a slender central displacement
22 hull 371 with a high length/beam ratio to facilitate wave piercing,
23 and a left lateral hull 373 also of slender type, with a similar
24 length beam ratio. Their first problem is a high friction drag
25 which increases with square of speed, as shown in qualitative curve
26 (c) of Fig. 30. When operating at a speed/length ratio of up to
27 about 3, drag is not excessive, and decreasing weight has small
28 benefits as shown in curve (d). However, when speed increases to

1 speed/length ratio of 5, which is the case for hull 393, friction
2 drag level becomes unacceptable in both curves (c) and (d). Also,
3 wave making drag becomes significant, due to shoulder curvature in
4 the planform of conventional hulls. Thus, the shorter length of
5 hull 373 has an inherent problem.

6 A quantified example of Fig. 31 is presented below:

7 Length of conventional center hull = 350 feet and its square root
8 is 18.7

9 Speed/length ratio, $V / \sqrt{L} = 3$

10 $V = 3 \times 18.7 = 56$ knots

11 Beam of center hull = 30 feet

12 Length / beam ratio $350 / 30 = 11.7$

13
14 The outboard hull of conventional design has a very different
15 hydrodynamic situation:

16 Length = 125 feet; its square root is 11.8

17 Length/beam remains same as center hull 11.7

18 $V = 56$ knots, as in center hull

19 However, speed/length = $56/11.18 = 5.0$

20
21 Its drag level at speed/length ratio of 5, for hull 373 is
22 therefore very high along curve (c) of Fig. 30, even if it had
23 smaller size and weight compared to center hull, for example along
24 curve (d).

25 In theory, a conventional planning hull, such as 375 shown in
26 dash lines in Fig, 31, could have less drag in the planning
27 condition at 56 knots, compared to conventional displacement hull
28 373 at the same speed, for example as shown in curve (e) in Fig,

30, but only in flat water. In normal ocean conditions, or in adverse seas, planning hull 375 would have unacceptable drag due to wave encounter, and high structural load as well rendering it impractical.

A more favorable situation applies for a trimaran hull using a slender central displacement hull such as 371 in Fig. 31 at speed/length ratio of 3 but with outboard hulls of transonic hull shape such as 377 in Fig. 31 of same or similar length as 373, but with a wider beam. Hull 377 could operate at high speed/length ratio of about 5, but its drag on curve (a) or (b) in Fig. 30 would be much lower than the conventional outboard displacement hull, as curves (c) and (d) shown in Fig. 30 for the speed/length ratio of 5.

As stated earlier, the drag curves of Fig. 30 are qualitative in nature, as their precise value for central and outboard hulls would depend on relative weights, beam loadings, length/weight ratios, and similar characteristics which are dependent on specific design choices. However, Fig. 30 are useful guides for a person familiar with multihull design theory and practice, to guide specific design choices.

In the prior review of problems of trimarans, the effect of rough ocean conditions has been mentioned in respect to wave piercing and structural loads, which in case of planning outboard hulls could be of the "slam load" type. This problem is alleviated if the wings supporting the outboard hulls are hinged at their root, for example by hinge 368 with toe in Fig, 29, or hinge 369 parallel to center line of Fig. 29. This type of arrangement, seen from the rear in Fig. 32, could be applicable to conventional, or

1 THE, or planning hulls. This generic case shown by way of example
2 in Fig. 32: wing 380 is hinged at its root hinge 381 to permit
3 angular motion 383 while its outboard hull 381 accepts lateral
4 ocean wave 382 with minimal slam loads and drag growth due to wave
5 encounter. Hull 381 could be of slender displacement type, or
6 alternatively, conventional planning, or TH type. Wing 380 is
7 mounted on center hull 379, which could be of any of the above hull
8 types, at hinge 381. Its angular excursion could be powered by the
9 lateral wave, and/or by hydraulic piston 383, or a combination of
10 power and damping by a hydraulic piston system similar to 383.

11 The prior figures 28 A to 32 described TH multihull
12 applications to large craft, but also representative of medium size
13 craft such as passenger boat, ferries, and military patrol and
14 coast guard boats, by scaling down as appropriate.

15 Moreover, TH multihulls are not size dependent, and can also
16 be applied to small boats and man powered craft with or without
17 auxiliary or emergency power devices. This is exemplified in a
18 kayak type craft specified first as a monohull, with additions of
19 lateral hulls thereafter.

20 Specifically Fig. 33 shows a monohull manpowered kayak type
21 hull 390 with flat sides and faceted top surfaces for ease of
22 manufacture, and / or assembly in the case of a kayak kit. Open
23 cockpit is shown as 391 and stern at 392. While manpowered speed
24 may barely reach supercritical range, the TH configuration as kayak
25 offers three important benefits: one is the feasibility for a
26 person to climb aboard in deep waters from the stern end, without
27 rolling the hull, improving in this unique way safety in an
28 emergency deep-water condition. Another is the ability of an arm

1 to execute paddle motion from a narrow cabin, enabling the arm to
2 remain close to the body, while retaining a broader beam for
3 lateral stability aft of the cabin. This is directly contrary to
4 usual kayak design, in which a maximum beam is at the cockpit. The
5 third advantage is smoother ride with less drag growth due to
6 encounter with a choppy sea surface, due to the very sharp entry
7 angle of the hull. The inch dimensions of a TH kayak are shown
8 below by way of example:

9
10 length overall = 162
11 water line length = 162
12 maximum beam at stern = 35

13
14 The flat sides of Fig. 33 can be generally vertical.
15 Alternatively, they can be inclined outwardly, for example, by
16 changing the bow angle to 393, similar to 395. This slides the
17 deck's planform 394 forward relative to planform of bottom surface,
18 signified as 396, thereby slanting the flat right side 397, and the
19 opposite side outwardly, as shown in Fig. 34.

20 Returning to Fig. 33, its typical crosssection 348 is also
21 shown in Fig. 35 as 398. However, Fig. 35 also shows hinged
22 lateral bodies to enhance lateral stability when deployed, by way
23 of example, on a TH hull, but applicable to all types of kayaks and
24 similar craft. Fig. 35 shows retracted right body 400 hinged at
25 axis 401 substantially above waterplane 402, so that the body 400
26 does not interfere with water surface 403 when the craft is in
27 motion. However, when lateral stability needs to be increased, for
28 example at slow speeds, or stationary, or in adverse seas, it is

1 deployed to position 400', with its lower surface when deployed
2 adjacent the water's level 402. When 400 is in position 400', the
3 center of buoyancy of the craft will shift asymmetrically when the
4 craft is heeled or rolled, volume of 400 is submerged, generating
5 a restoring moment to the craft, for example with water level 403
6 representative of the heeled condition.

7 Fig. 36 shows an isometric view of the body of Fig. 33 with
8 lateral stability bodies of Fig. 36 in the 400 retracted condition.
9 Fig. 37 shows the same craft with the stability bodies in the
10 deployed 400' condition.

11 Prior discussion of manpowered TH type kayak has mentioned
12 lateral stability issues and auxiliary or emergency propulsion.

13 Lateral stability can be improved for a TH kayak, or any type
14 of kayaks, by means of an asymmetric auxiliary hull, or "proa"
15 configuration, such as shown in Fig. 38 with main hull 405, and a
16 lateral or auxiliary hull 406, supported by wing 407. Body 405
17 should be small so as not to generate drag and weight. Hence,
18 there is special benefit for 406 to be of TH type, because at or
19 near critical speed of main hull 405, auxiliary hull 406 is
20 evidently operating in transplanar regimes, due to its short
21 length. Moreover, it can encounter water chop of large size
22 relative to its length and beam, which means that the TH offers a
23 separate gain, compared to conventional slender displacement shape
24 used for a lateral hull. The TH shape of auxiliary body 46 is
25 specified in Fig. 39.

26 Specifically Fig. 39 shows the top view of main TH hull 405,
27 side wing 407 and lateral body 406, with the corresponding side
28 view in Fig. 40. Coordinates and dimensions are in inches for a

1 manpowered craft, but could be feet for a small ferry or military
2 craft, and meters for a larger craft, with different top surfaces.

3 The coordinates and sections of lateral TH body 406 are shown
4 in Fig. 41. The X (longitudinal) and Y (lateral) coordinates can
5 be increased for a lateral body of greater buoyancy, for example,
6 with a factor up to about 1.6 and the X coordinates for a more
7 slender body, for example, with a factor of up to 2.0,
8 approximately, without change in principal TH hull. The asymmetric
9 shape is designed to reduce tendency of adverse roll on a lateral
10 sea.

11 Fig. 42 shows a TH trimaran with auxiliary or emergency
12 propeller, the inventive aspect of which is described below:

13 The use of air propellers, ducted propellers, and air fans for
14 moving water craft is known, but has been restricted to special
15 fields, for example boats for use in swamps and shallow waters,
16 usually with hulls having rectangular planforms and large beams,
17 with length to beam ratios of approximately four. Air propellers
18 have also been used on ground effect machines, also of similar
19 rectangular planforms, capable of operating over the water or land,
20 such as Hovercraft. Moreover, air propellers have been proposed
21 and used for propulsion of hulls of seaplanes, which are slender
22 but have wing aerodynamic lift at high speeds.

23 On the other hand, manned powered watercraft such as rowing
24 shells, kayaks, and similar boats have used oars, paddles, and even
25 the interesting moving fins as used in the very efficient
26 propulsion unit of Hobie Mirage kayaks. All these boats are
27 slender.

28 Kayaks and similar boats have also considered the use of

1 marine propellers powered by leg motion, as shown in the internet
2 under various names, and even the use of electric driven marine
3 propellers as auxiliary power plants, or as emergency power plant,
4 or as alternative power plant, requiring batteries to drive the
5 electric motors which drive marine propellers. One serious
6 impediment is encountered when beaching such manpowered craft with
7 marine propellers protruding below the surface of the water,
8 normally requiring that they be retractable, which adds complexity
9 and cost to such craft. They also add drag when motion is
10 restricted to oars or paddles, and batteries of standard type,
11 though low in cost are very heavy, and can reach the weight of an
12 entire single place kayak. However, air propellers to provide
13 auxiliary driving thrust with battery power of slender craft is
14 unprecedented, until the present invention.

15 Hence the present invention pertains to the use of aerodynamic
16 propellers, or ducted propellers, or fans, hereafter referred to as
17 aerodynamic impellers, in an unprecedented and unique application
18 for slender manpowered vessels, as alternative, auxiliary, or
19 emergency powerplants, using batteries which can be charged on
20 shore, or charged/recharged with solar panels on the surface of the
21 manpowered craft.

22 Special slender TH boat configuration which provides new
23 unique features are specified in Figs. 42 and 43. The principal
24 features of Fig. 42 are as follows: Principal TH hull 409 support
25 lateral wings 411 and 410, which in turn support outboard TH hulls
26 413 and 412. Rear deck 414 supports electric motor 420 which
27 drives air propeller 415 using battery 421.

28 The large upper surface area of the TH trimaran should be used

1 for solar panels in the figured shaded area 416 (top of forward
2 deck), 417 (top of wings), and 418 (top of rear deck), to charge
3 batteries when on route on top of a car or on a trailer, when
4 stationary on a beach, or when rowing. The inclined panels 416 and
5 418 have a shallow angle, up to 45', to optimize capture of solar
6 energy early morning or late afternoon.

7 Also, the wings can be folded upwards for transportation about
8 hinge 419, or downwards relative to hull 409, to catch afternoon
9 rays of the sun, for example by tilting hull 409 on the beach, or
10 by heeling the hull in the water.

11 Because air propeller 415 could create problems for persons
12 not used to propeller driven vehicles, it is preferred, and
13 recommended by this writer, that aerodynamic propulsion should use
14 a shroud or duct. Small light electric motor 420 is powered by
15 batteries 421 mounted at a low position inside the hull, thus
16 avoiding need to have a transmission. A brushless motor is
17 preferred for greater efficiency and cool running temperature.
18 Light weight batteries such as nickel-metal hydride, or even
19 better, expensive ion-lithium batteries, would minimize vehicle
20 weight. High efficiency of battery and electric motor will be key
21 for light weight needed in a man powered craft, because it needs to
22 be carried, often by hand from shore to a car. Added cost provides
23 added safety, and with the propeller as in Fig. 42, there is no
24 obstacle to beaching the TH trimaran.

25 Moreover, unique added features are needed surrounding the
26 propeller's disc, to prevent accident. A safe alternative is the
27 use of a ducted propeller shown in Fig. 43, comprising duct 423
28 mounted on rear deck of hull 409, with an internal impeller 425 and

1 a frontal louver or mesh 426, to impede accidental insertion of a
2 hand, or air-driven rags. A similar mesh should be used on the
3 ducts rear mouth, which can also have an air rudder 428. The
4 external upper and side surfaces of the duct can also have solar
5 panels symbolized as 429, further increasing solar panel area.

6 The folding feature of the wings supporting the lateral hulls
7 is shown, by way of example, in Fig. 44, for the "proa" of Fig. 38,
8 with hand retracted position over and across the hull, and hand
9 driven deployment path 430 for deployed position of Fig. 38. Fig.
10 45 shows half of the retracted position for the trimaran of Figs.
11 42 and 43, with deployment path 431. Similar retracting and
12 deployment methods can use electric or hydraulic acceleration,
13 specially for larger craft.

14 Fig. 46 shows a new type of stern planform for TH
15 configuration using a vee exit. The flow below the hull now has
16 different subcritical pattern shown in Fig. 47, comprising two
17 separate semi-gothic arch wake planforms 432 and 433 which occur at
18 different Froude numbers than for a rectilinear stern planform, as
19 has been established experimentally. The subcritical flow becomes
20 a single supercritical wake between rays 434 and 435 at a different
21 Froude number, compared to that for a supercritical regime of a
22 non-vee TH stern planform.

23 The numerical values of the design criteria mentioned above
24 are representative for the hull characteristics reviewed, and may
25 be adjusted for specific TH hull shapes with full size weights,
26 corresponding thrust line positions, and other design features
27 within the spirit of the invention and its claims.

28 The specifications and drawings pertain to hydrodynamics and

1 TH shapes and does not cover structural details of mechanisms, and
2 because model tests are not sufficient for determining stability of
3 full size manned TH of unknown weight, or other safety related
4 matter, these matters should be investigated and determined solely
5 by licensed manufacturers, who have the sole responsibility in such
6 matters.

7 Changes can be made on the drawings and specifications without
8 departing from the teachings as covered in the claims of the
9 invention.